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BIOLOGICAL TREATMENT OF CONCENTRATED SUGAR BEET WASTES

James H. Fischer

Beet Sugar Development Foundation

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PB 240 123

Biological Treatment of Concentrated Sugar Beet Wastes

James H. Fischer

12060 FAK

Beet Sugar Development Foundation
P.O. Box 1546
Fort Collins, Colorado 80521

Environmental Protection Agency report number, EPA-660/2-74-028, June 1974

A study of the variables influencing a closed loop recirculating flume water system for conveying sugarbeets for processing was conducted at Longmont, Colorado. Settleable solids were removed by screening, addition of milk of lime and settling; the concentration of dissolved solids increased daily during the processing season. The increasing concentration caused no problem provided the pH was 10 or greater and that the water temperature did not exceed 20°C. A deep anaerobic pond received surplus system waters and the total system waters when operations ceased. Anaerobic digestion was aided by addition of nutrients and odors reduced by surface aeration. Water eventually met discharge standards, and was used the second year to fill the system.

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BIOLOGICAL TREATMENT OF CONCENTRATED SUGAR BEET WASTES

By
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Project 12060 FAK
Program Element 1 BB037
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ABSTRACT

A study of the variables influencing a closed loop recirculating flume water system for conveying sugarbeets for processing was conducted at Longmont, Colorado. The results show that high volume, high total solids transport (flume) waters can be recirculated with little or no discharge to receiving waters. Rapid removal of suspended solids was accomplished by screening, followed by continuous addition of lime prior to sedimentation. The build-up of total dissolved solids was no major problem during the operation periods, provided the pH was 10 or greater and that water temperature did not exceed 20°C.

The system was designed for primary settling in two alternately used ponds. Settled mud was removed from one pond by clamshell while the other one was in service. The first settling pond effluent was subjected to secondary settling before returning to the fluming and washing operations. These segments of treatment essentially operated without odor.

A deep anaerobic pond designed to degrade remaining solids in the surplus water was effectively used to treat the total system waters at the end of each operating campaign. Floating surface aerators were used with success the first year to reduce odor but failed to be consistently effective the second year. The aerators were effective in helping final polishing to meet discharge standards.

Biological and nutritional data were collected to evaluate operational quality, water quality and bio-activity. While the results indicate that the end product water meets discharge standards, such treated wastes were retained for re-use in the system. Further work is needed on mud handling and odor abatement.

This report was submitted in fulfillment of Project Number 12060 FAK by the Beet Sugar Development Foundation under partial sponsorship by the Environmental Protection Agency. Work was completed as of October 1970.

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SECTION I

CONCLUSIONS

The principle of total recirculation of sugarbeet factory flume and wash waters has been proven to be successful. Best results are obtained when adequate quantities of lime, as CaO, are continuously injected into the system at a rate sufficiently high to produce a pH greater than 10. To maintain a high pH with minimum lime addition, the system waters should be kept under 20°C.

Under the above conditions, settleable solids can be rapidly concentrated into a mud that can be removed in ponds or in a typical clarifier. The supernatant can be returned with minimum retention or no retention to repeat the fluming-washing cycle. The continuous build-up of dissolved solids does not interfere with the hydraulics but does aggravate the foaming problem. Odors are not a problem under high pH conditions.

The loss of system water with the settled mud seems to equal an inherent make-up. No water needs to be discharged during an operating campaign, therefore, there need be no concern over water quality from this source. Removal and handling of settled mud, however, is a continuous problem.

After an operating campaign the system waters are bio-degradable and can be ponded for re-use as has been done at Longmont for 3 years consecutively. None of the methods used to date has accomplished the degradation process without periods of high odors. A true anaerobic or aerobic condition was never attained with or without mechanical surface aeration; a facultative condition existed. However, the residue water received sufficient treatment to meet discharge quality standards even though the time required exceeded expectations.

SECTION II

RECOMMENDATIONS

The Longmont waste water treatment system, with modifications, is recommended for use in geographical areas where the system waters do not exceed 20°C. Higher temperatures increase fermentation rates and lime requirements. Even then, the liming principle does have application as an economic aid to hasten settling of solids.

Two main problems remain to be solved. It is recommended that further research be conducted on the dewatering and transport of settled mud. Odor production from settled mud in ponds continues for prolonged periods of time. Standard methods of dewatering are either too costly or do not perform to satisfaction under normal conditions.

Further research is recommended on the treatment of end of campaign residue water. The anaerobic or facultative methods of treatment produce unpleasant odors. Several types of aerobic systems should be tried on sugarbeet wastes. Because of limited land availability at many factory sites, the aerobic approach would not be applicable to all factories. It is recommended that further studies be conducted on anaerobic-facultative ponds using coverings or controlled digestion with specific organisms.

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SECTION III

INTRODUCTION

The process of refining sugar from sugarbeets originated in Europe following the first actual proof by Andreas Marggraf, a German chemist, in 1747 (2) that beet roots contained sugar. No use was made of this discovery until 1799 when one of his pupils, Franz Karl Achard, recovered sugar from a small planting of sugarbeets. Napoleon himself ordered the first large-scale planting of sugarbeets and the extraction of sugar from the roots in 1811. Although some evidence exists that the California Indians extracted sugar from beets prior to the European development, the European continent is credited as the birthplace of the beet sugar industry.

Following numerous unsuccessful efforts, the first generally accepted commercial success to produce sugar from sugarbeets in the United States is acknowledged to have been accomplished by E. H. Dyer at Alvarado, California in 1879 (20).

The factory at Alvarado continued in operation through 1967 at which time the Holly Sugar Corporation elected to terminate its operation and dismantle the equipment. One of the significant influences on the decision by Holly to terminate a near-century operation was the problem and cost of waste disposal. The encroachment of the Bay area population around the factory site created numerous problems in community-industry relations. This historic beet sugar factory thus has yielded to urbanization. This is a typical example of similar conditions existing at other beet sugar factory sites and with other processing industries.

The technology of American industry has not yet advanced to the point where factories are welcome to operate adjacent to residential and business areas. Perhaps the day will come as processing techniques become more sophisticated. Each present-day development in environmental control is a building block in this direction.

The beet sugar industry is a typical American business enterprise. It has its problems of air and water pollution. With the advent of increasing public sentiment to clean our air and water, it behooves the sugar industry to reduce its contribution to pollution as rapidly as technology and economics permit.

The work here reported is essentially devoted to the problems of treating and disposing of wastes encountered in the water used to transport

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the beets in the factory and to wash the beets. Other sources of waste such as process water, lime cake drainage, Steffen process waste, condenser waste, etc. will be mentioned from time to time only to place the entire discharge of wastes from a beet sugar factory into perspective.

Several sources have reported (20) that the total waste load from a factory capable of processing 2,000 tons of beets per day is roughly equivalent to that from a city of 252,000 people. Eldridge (8) reports that 17.6 percent of the 5-day Biochemical Oxygen Demand (BOD_5) discharge from a factory will be in the flume water. However, this discharge accounts for 72.1 percent of the hydraulic volume. Excepted from these figures is condenser water, a high volume, low BOD_5 waste.

Recent reports by visitors returning from Europe have stated that considerable success has been experienced in both water conservation and waste treatment by applying recirculation or closed-loop systems to the high volume water requirements of a factory. Particularly these reports apply to the fluming and condenser waters. In the case of fluming water, lime as CaO has been metered into the water to hasten precipitation of settleable solids and to retard bacterial reproduction.

Several significant differences exist between European and North American beet sugar processing campaigns. In the first place, European campaigns are shorter than the average U.S. campaigns and are limited to late fall and early winter. Secondly, nearly half of the U.S. beet sugar production comes from sugarbeet roots that have been stored in large open piles, whereas, only a small percentage of the European beets has been subjected to short storage periods in small on-the-farm piles. Thirdly, the climate in western Europe is quite uniform through the entire processing season with small temperature changes. In contrast, the North American sugarbeet processing campaigns are in progress, at one location or another, 12 months ot the year.

European sugarbeet production and processing practices cannot be translated to North America without modification to correct for environmental influences. The same is true within the North American continent. Operational procedures in the southern part of California and southern Arizona are quite different from those in North Dakota and Montana, and the provinces of Canada.

Prior to initiating this study the influence of geographical location was recognized. The proposed plan of operation included an analytical program to guide the system operation and to predict the adaptability of limed, recirculating (or closed loop) flume water systems to different factory sites. It was agreed that a modified approach to several success-

ful European systems of this type showed considerable promise for adaptation in the North American continent. At the time of project planning some limited trials with limed, recirculating flume water were also being planned by several U.S. and Canadian beet sugar companies.

Following several industry-wide conferences on the subject of flume waste water treatment, the industry agreed to begin a study of the problem through the Beet Sugar Development Foundation. An application for supporting funds was submitted to the Environmental Protection Agency (formerly the Federal Water Quality Administration). The proposal suggested the construction of a full-scale recirculating system at The Great Western Sugar Company at Longmont, Colorado. Longmont is within a geographical area which has climatic conditions relatively mean to those existing within the states where processing plants are located.

The objectives were to develop a system for economic treatment of sugar-beet factory flume (conveying and washing) water permitting its re-use in a recirculating fluming system. The system should operate without odor during and following the campaign. Any water surplus from the system during operation, as well as the residual water after campaign, was to be treated in a manner to meet discharge quality standards.

The plan of operation called for the addition of lime, caustics or other chemicals to determine their effectiveness on control of pH, removal of settleable solids and retention time. The precise treatment for the surplus and residual water was not described since results of research in progress were being awaited. Ultimately, the anaerobic approach was selected by employing the principle of deep ponding and surface aeration.

SECTION IV

DESIGN AND CONSTRUCTION

The typical sugarbeet processing factory is designed to process either freshly-harvested sugarbeets directly from farmers' fields delivered by rail or truck or from large storage piles located at or near a factory. All sugarbeets are mechanically harvested by the farmer (or a contractor) and delivered to receiving stations located on the factory premises and at convenient outlying sites. The receiving stations are equipped with dry mechanical cleaning devices to separate the most easily-removed dirt, clods, rocks, weeds and green leaf material from the fresh roots. In some states the tare (removed material) is returned to the individual farmer's field; in other states it must be retained at a single location by the sugar company. Most of the additional adhering dirt and extraeneous material is removed from the beets at the factory by the fluming and washing operations.

Each beet sugar factory has an individual design for fluming and washing operations. With few exceptions, each one will have a receiving hopper or hoppers with flume water underflow. Some installations, particularly for rail deliveries, will have high pressure overhead hoses that assist in evacuating the cars. In cold climates, the water source to the overhead sources is heated to thaw the frozen conglomerate of sugarbeets, mud, dirt, rocks, etc.

From the receiving hoppers, the flume water transports beets through a series of cleaning devices to remove sand, rocks, clods, organic matter, metal, etc. A final high-pressure spray above the spray rollers is the last cleaning operation prior to the slicing of the sugarbeets into cossettes.

Historically, the flow design for fluming and washing provided for fresh water input to the system and the discharge to holding ponds or to receiving water bodies. The design reported in this study provides for the complete containment and recirculation of all fluming and wash water.

The schematic flow diagram, Figure 1, will show an early and important decision made in designing the flow pattern. The total flume and wash water flow is not limed. Approximately one half is returned to the flumes from the screens without being limed. The remainder of the flow is limed, clarified and returned to the flume where it is mixed

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with the untreated flow. The proportion of treated to untreated flow becomes a part of the study.

In discussing the design and construction, only those system components which are unique to the project will be given consideration. A discussion of typical hydraulic components will be included only if they have had particular influence on the operation and results.

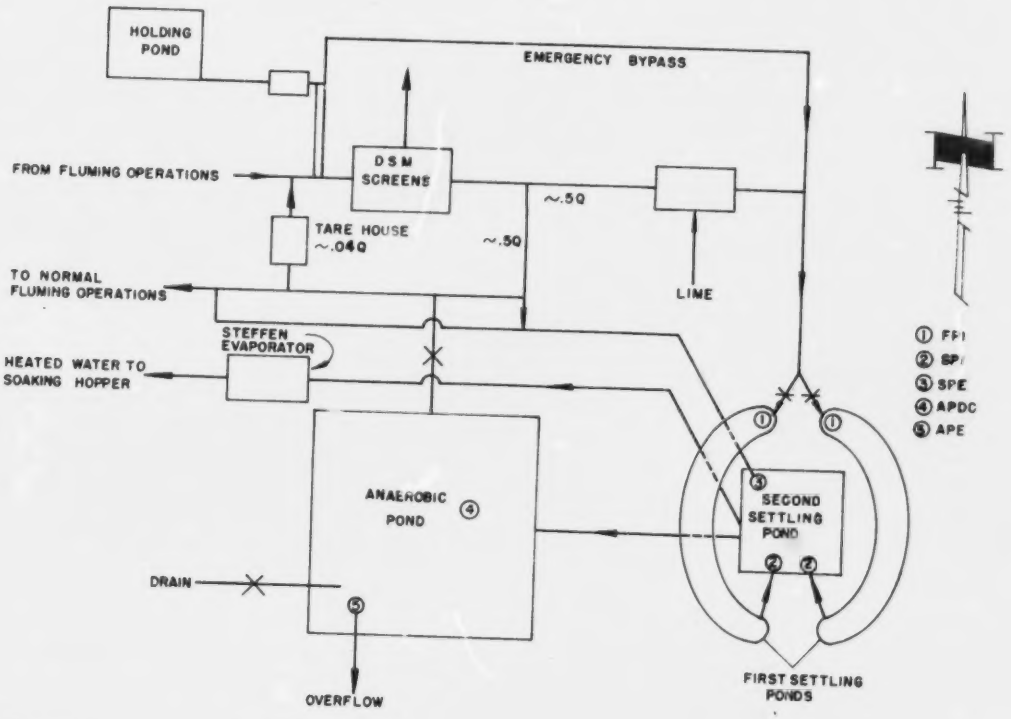

FIGURE 1. SCHEMATIC FLOW DIAGRAM OF LONGMONT FLUME SYSTEM.

The existing fluming system at the Longmont factory of The Great Western Sugar Company between the receiving hoppers and the spray rollers was only slightly modified. One major change was made at the confluence of several waste streams before their discharge to the old settling ponds. The design provided for the collection of the flume water into a sump at which point it is pumped up into a manifold supplying waste water to the elevated screens. Valves control the flow to each screen (Figure 2).

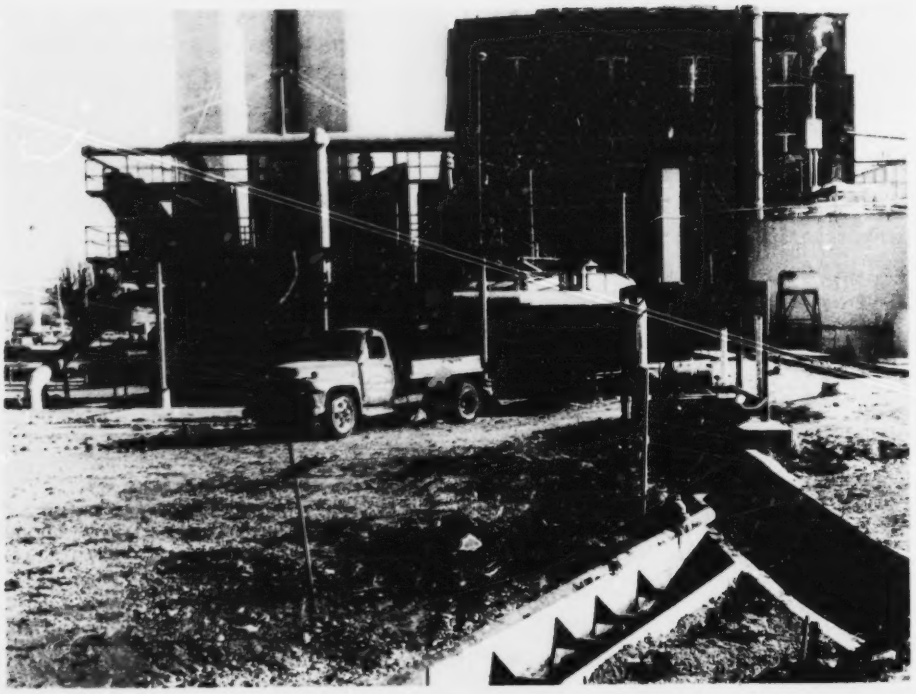

FIGURE 2. ELEVATED DSM SCREENS SHOWING MANIFOLD AND VALVE SYSTEM.

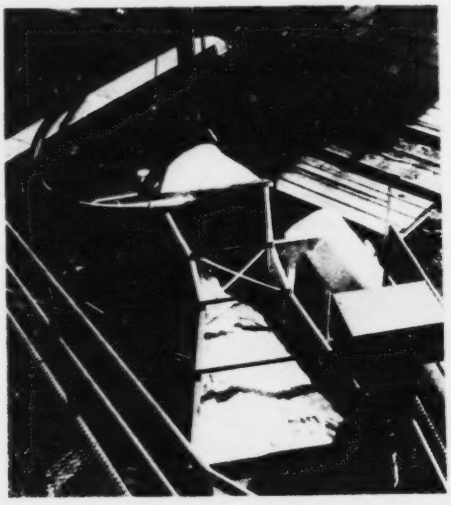

FIGURE 3. PARSHALL FLUME AND HOSE ARRANGEMENT FOR ADDITION OF MILK OF LIME.

The final screen design included five stationary screens operating in parallel. Four of the screens were Dorr-Oliver DSM screens. Three had 3 mm openings and one screen had 6 mm openings between the stainless steel bars. The fifth screen was of similar design. However, it had a longer and wider contact area with 6 mm openings. The rejects from the screens drop to a trash platform and the underflow is collected in a receiving manifold. The manifold divides the flow, about half of which returns to the flumes. This flow is metered. The remainder of the flow (that which is treated) is measured through a Parshall Flume (at which point milk of lime is added, see Figure 3), passes through a mixing box and is piped to the first settling ponds, only one of which is used at a given time.

Considerable discussion preceded the decision to use the two-pond design, rather than install a typical clarifier. Both plans would require a system for handling settled mud. The selected design requires clamshell removal of settled mud from the alternately-used first ponds during campaign. The selected design does not represent a preference, but a means to reduce initial capital investment.

Figures 1 and 4 show the two semicircular first ponds lying outside the perimeter of the central second settling pond. The flow can be directed to either of the first ponds, the duration of flow to each being dictated by the rate the settled mud accumulates and the percentage of settleable solids remaining in the first pond effluent. Since evacuation of mud from the ponds is accomplished by clamshell, wide dikes were planned to permit ease of access.

Flow to the second settling pond from either of the first ponds is by gravity. In addition to the second pond serving as a second settling pond, it serves as a surge basin. From the second pond, water is pumped back to the flumes thus completing the cycle.

The anaerobic pond located to the side of the first and second ponds serves as a reservoir. Water can be introduced into this pond through a gravity syphon flowing from the second pond or can be pumped directly to the pond from the recirculating system. Transport water is pumped from the flumes and the first and second ponds at the end of campaign. Conversely, anaerobic pond water can be pumped back to the recirculating system as make-up water.

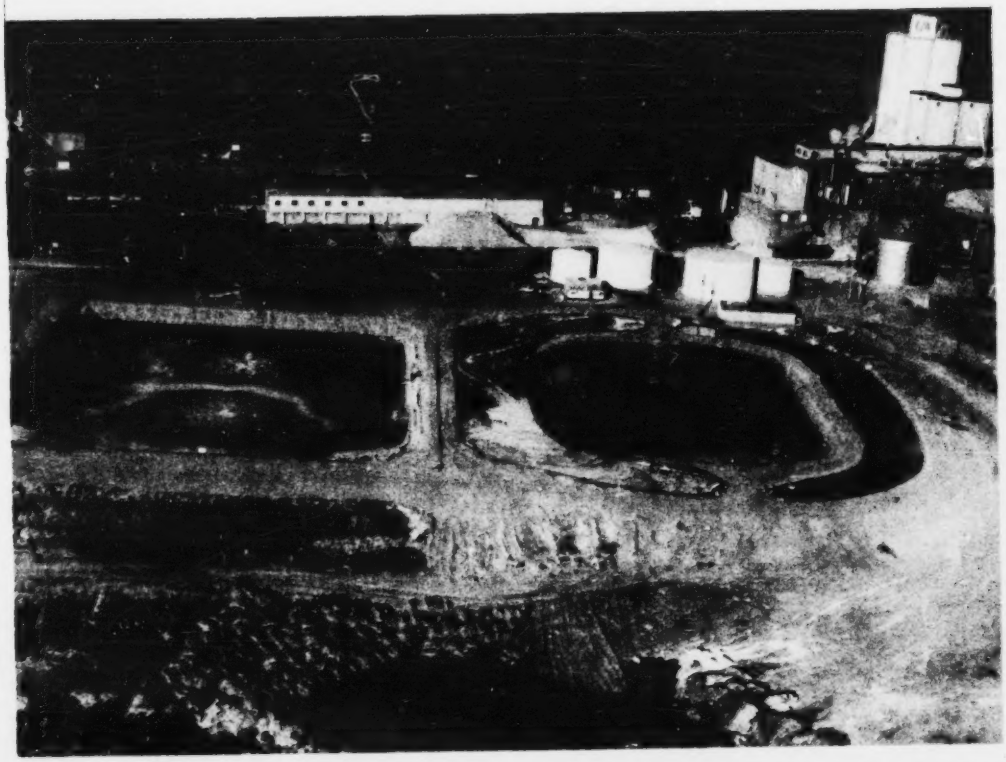

FIGURE 4. AERIAL PHOTO OF PROJECT SITE AND TREATMENT PONDS.

The hydraulic design included provisions for emergency discharge. Should the anaerobic pond be unable to contain the surplus waters, water is wasted through a standpipe to a slough, and thence to the river. Similarly, water can be wasted to the lime holding ponds where the other miscellaneous factory wastes are retained.

SECTION V

EXPERIMENTAL

General

It is important to mention that the experimental work described in this report was superimposed upon the commercial processing schedule of the Longmont factory of The Great Western Sugar Company. Ideal conditions for experimental control were not always present. In recognition of the typical events that transpire during a processing campaign, the design was developed to minimize interference with the normal operation.

Under existing conditions, the variable quantity of sugarbeets delivered to the flumes, the changing water flow rates, changes in water temperatures and other variables were normal operational fluctuations. The control and analytical schedules were designed to meet these variable conditions as they developed. A fully-equipped mobile laboratory was moved to a location on the factory premises conveniently near the sampling points. The existing factory process control laboratory was inadequate to provide increased analytical activity.

The sampling and analytical schedule allowed for the measurement of all flows wasted from the factory excluding domestic wastes. Although this study was primarily conducted on the flume water, samples were routinely collected from the condenser water sewer and on irregular schedule from other waste streams. As unusual situations developed, supporting bench and system studies were conducted. Reports of these are appended as part of this report.

The experimental results reported cover the two operating campaigns of 1967-68 and 1968-69. The principal emphasis has been placed on the 1968-69 data since some irregularities in the system's physical performance during the first year influenced the validity of some of the results. Design modifications prior to the second campaign corrected nearly all of the hydraulic problems which had confounded the 1967-68 results.

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Sample Colletion

In most instances the samples for chemical analysis were taken at the same location and at the same time as those for biological analysis. The chemical samples and physical data were acquired and processed at Longmont. The biological samples were shipped immediately after collection to the Department of Microbiology at Colorado State University in Fort Collins for processing. The data were evaluated by computer at the Statistical Laboratory, Colorado State University.

In order to ascertain the fate of the chemical and biological constituents in the system, five sites were selected as sampling stations (Figure 1). The first pond influent (FPI) was designated as the initial sampling point. The actual sampling point was located 6 feet distant from the discharge of the pipe carrying water from the Parshall flume and lime mixing box into the ponding area. Samples collected at this point contained the mixed scre ned underflow and slurried lime.

The second point of sampling was located 6 feet distant from the discharge of the overflow between the first and second ponds and was designated as the second pond influent (SPI). This site was selected to determine the rate of which suspended solids would settle in the primary pond and to determine the ratio of percent settleable solids removed to detention time.

The third sampling point was at the outlet of the second pond at which point the water was returned, by pumping, to the flumes. This site was selected as the operations control point. At this location the total change occurring across the ponds would be maximum. The differences between the FPI and SPE reflected the removal efficiency of the pond system and the SPE values established the amount of lime addition for each selected pH parameter.

The fourth sampling points were located in the anaerobic pond. Two representative locations were established on the pond centerline that were equal distance from each other and the opposite two shorelines. These points were each sampled at 3-foot vertical intervals. Initially, an attempt was made to determine depth and location differences. Since differences between depth intervals and location for both physical and biological data were minimal, individual analyses were abandoned. However, the sampling procedure was maintained to produce an anaerobic pond depth composite (APDC).

The fifth sampling point was at the anaerobic pond effluent (APE). During the 1967-68 campaign there was a planned and continual discharge from this point which required make-up water. During the 1968-69 campaign there was no discharge from the anaerobic pond, thus no samples were taken; infrequent make-up water was required.

Automatic samplers were used at the first pond influent, second pond influent and second pond effluent. The automatic samplers were used to collect samples for chemical analysis only and were time-programmed to collect a total of 2.5 gallons during a 24-hour period at a rate of 12 sub-samples per hour. The sampling tubes were protected from freezing with heat tapes. Standard grab methods were used for surface and depth samples for dissolved oxygen, BOD_5, and biological analysis (1).

The analytical schedule, analytical procedures and a description of sampling methods used are shown in Tables 20 through 32 and in the appendix.

Analytical Procedures

The numerous questions relating to the efficiency and operation of the system were of hydraulic, mechanical, chemical and biological nature. It became apparent that each of the stream flows associated with the system required quantitative evaluation. Each of the flows was measured with an appropriate metering device. Although the performance of standard pumps, screens, valves, etc. were known, some questions concerning durability under the design conditions were not answered until placed under test.

The bulk of the analytical program involved the completion of the chemical and biological analyses. Table 22 in the appendix gives a detail of the routine schedule for the primary constituents believed to have an influence on the system performance. Each of the analyses was rather routine excepting that for total carbon. It had been reported that a measure of the organic carbon in waste water might prove to be an accurate substitute for measuring BOD_5 loads in waste water (37). A total organic carbon analyzer was used to obtain a value which was then related to both BOD_5 and COD measurements. Table 24 in the appendix outlines the analytical schedule for biological analyses. Since

the bio-samples were acquired differently than the chemical samples, chemical analyses were also performed on a composite of weekly bio-samples. Table 25 in the appendix gives the analytical schedules for the weekly mud samples composited from 24-hour daily samples taken from the first pond influent. The hydraulic and physical data schedule is given in appendix Table 26.

SECTION VI

DISCUSSION

During Campaign Studies

Lime Addition and pH

The main operating parameter of the ponding system was pH. The system was operated in such a manner as to determine the effects of selected pH levels on the system and the effects of other influences such as water temperature on pH control. Calcined lime rock (CaO) was slurried with hot water and differential amounts were added to the influent to the first pond in order to achieve and maintain various pH levels in the system(5).

Such pH control was designed to neutralize organic acids and inhibit biological activity. The system was operated for the first 6 weeks at various pH levels. Lime addition was the only variable during this interval. After this period, heated water was added to the system to thaw frozen sugarbeets as an operational necessity.

Other investigators have reported a correlation between pH control of a flume water system and the amount of dissolved oxygen in flume water (38). From Figure 5 it can be seen that pH and dissolved oxygen did correlate well, and that high levels of dissolved oxygen corresponded to high (or rising) pH levels. Also note that greater pH losses were encountered during periods when dissolved oxygen did not carry through to the second pond.

At first glance it would appear that the amount of dissolved oxygen in the system was a function of the pH. That is, high pH levels inhibited biological activity and reduced the consumption of oxygen. Therefore, dissolved oxygen carried through the system.

Comparison of Figure 5 with Figure 6 shows a negative correlation between temperature and dissolved oxygen and a positive correlation between return flow rate and dissolved oxygen. It is, therefore, impossible to separate the individual effects (on pH control) of each of these variables.

During the periods in which the amount of lime addition was the only influencing factor on pH, it was found that the control pH (SPE pH)

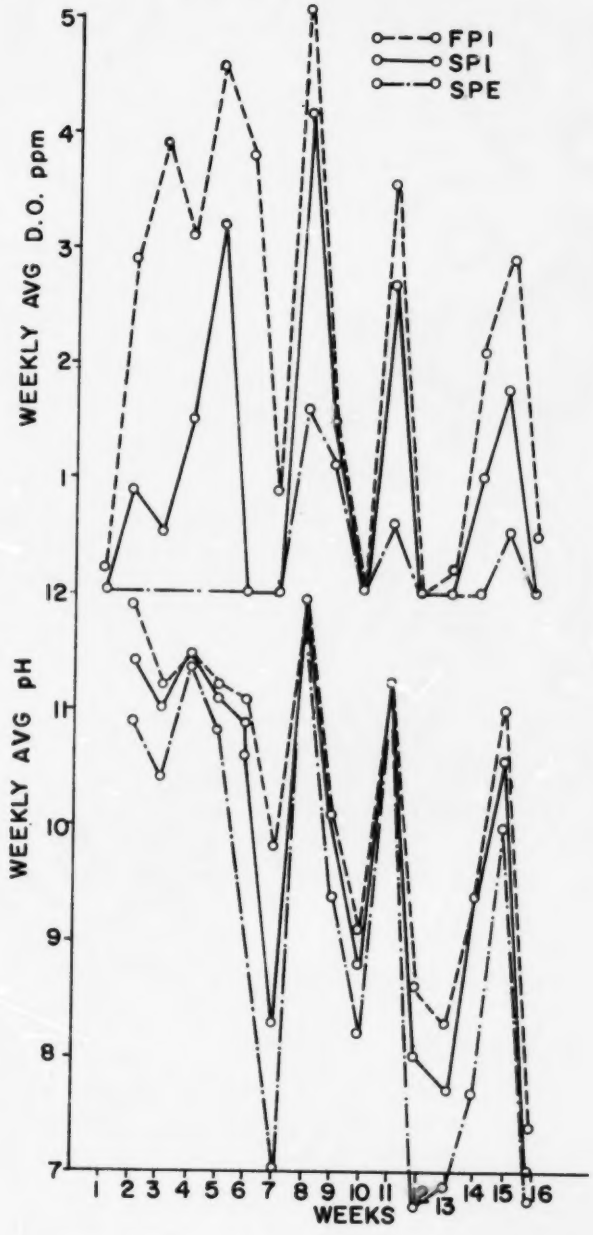

FIGURE 5. RELATION OF DISSOLVED OXYGEN TO pH AT THREE SAMPLING POINTS.

could be raised from 7 to above 10 by the addition of from 14,000 to 16,000 pounds of lime per day (Figure 6). The pH could be maintained above 10 by the addition of from 7,200 to 9,600 pounds of lime per day. Early in campaign, the control pH was maintained above 10 by the addition of as little as 6,000 pounds of lime per day, but as time progressed more lime was required to accomplish this feat possibly indicating the influence of increasing organic sludge accumulations.

From the lime addition study, it would appear that less time is required to maintain pH levels above 10.0 than to maintain pH levels below 10.0. This conclusion came from the fact that the system was never considered to be under pH control when the pH was below 10. This is probably due to increased bio-activity when the pH was below 10.0.

To further understand this phenomenon, an additional study was undertaken. Grab samples were taken from the first pond influent, analyzed for alkalinity and pH and placed in the incubator @ 20°C ± 1°C for a period of 4 hours. After this 4-hour period the samples were once again analyzed for alkalinity and pH.

A total of 17 samples were examined in this study where the original pH ranged from 9.0 to 12.0. The study covered 30 days of factory operation and one sample per day was analyzed from 3 to 5 times a week. The results of this study are summarized in Table 1. For purposes of tabulation, Table 1 samples were categorized according to original pH range. The results of this study show that minimal reductions in alkalinity occurred when original pH was above 10.0.

TABLE 1. -- pH AND ALKALINITY STUDY FPI GRAB SAMPLES, 1968-69 CAMPAIGN.*

Original pH range	Number of samples in range	Alkalinity reduction in 4 hours ppm CaO	
		Mean	Range
11.5-12.0	3	39	33-43
11.0-11.5	7	47	17-64
10.5-11.0	2	41	34-48
10.0-10.5	2	42	29-56
9.0-10.0	3	132	72-203

*samples analyzed, held at 20°C for 4 hours, samples re-analyzed.

could be raised from 7 to above 10 by the addition of from 14,000 to 16,000 pounds of lime per day (Figure 6). The pH could be maintained above 10 by the addition of from 7,200 to 9,600 pounds of lime per day. Early in campaign, the control pH was maintained above 10 by the addition of as little as 6,000 pounds of lime per day, but as time progressed more lime was required to accomplish this feat possibly indicating the influence of increasing organic sludge accumulations.

From the lime addition study, it would appear that less time is required to maintain pH levels above 10.0 than to maintain pH levels below 10.0. This conclusion came from the fact that the system was never considered to be under pH control when the pH was below 10. This is probably due to increased bio-activity when the pH was below 10.0.

To further understand this phenomenon, an additional study was undertaken. Grab samples were taken from the first pond influent, analyzed for alkalinity and pH and placed in the incubator @ 20°C ± 1°C for a period of 4 hours. After this 4-hour period the samples were once again analyzed for alkalinity and pH.

A total of 17 samples were examined in this study where the original pH ranged from 9.0 to 12.0. The study covered 30 days of factory operation and one sample per day was analyzed from 3 to 5 times a week. The results of this study are summarized in Table 1. For purposes of tabulation, Table 1 samples were categorized according to original pH range. The results of this study show that minimal reductions in alkalinity occurred when original pH was above 10.0.

TABLE 1.-- pH AND ALKALINITY STUDY FPI GRAB SAMPLES, 1968-69 CAMPAIGN.*

Original pH range	Number of samples in range	Alkalinity reduction in 4 hours ppm CaO	
		Mean	Range
11.5-12.0	3	39	33-43
11.0-11.5	7	47	17-64
10.5-11.0	2	41	34-48
10.0-10.5	2	42	29-56
9.0-10.0	3	132	72-203

*samples analyzed, held at 20°C for 4 hours, samples re-analyzed.

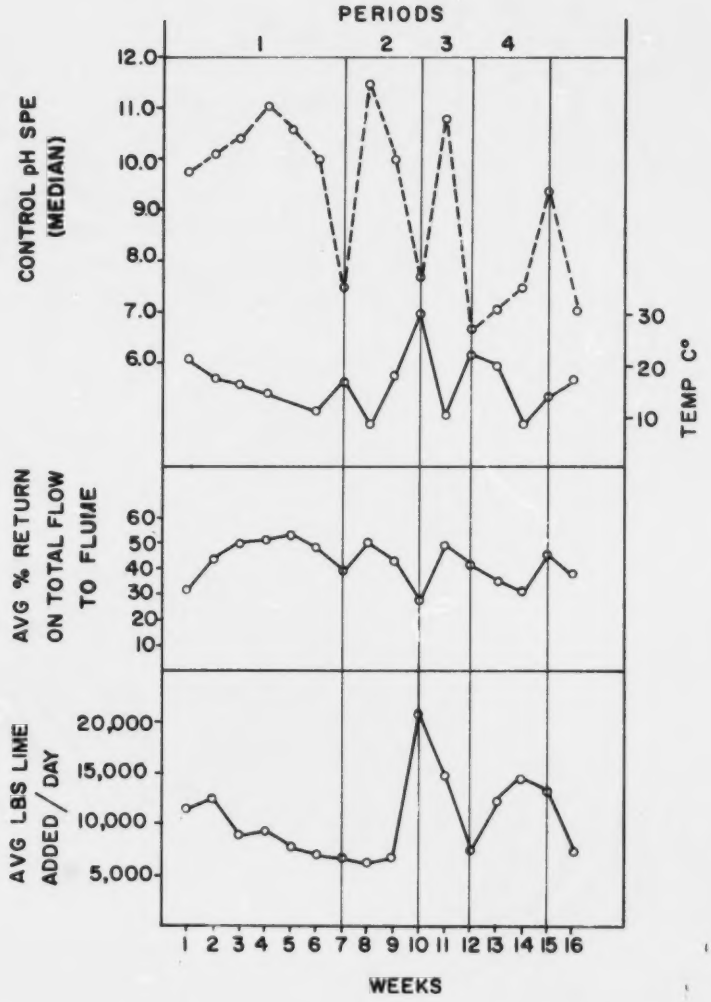

FIGURE 6. THE RELATION OF LIME ADDITION TO pH AT THE SECOND POND EFFLUENT. THE PERCENT UNTREATED RETURN FLOW IS SHOWN.

To further substantiate these data Table 2 was developed. Grab samples from the first pond influent, second pond influent and second pond effluent were analyzed for pH three times a day for the entire 1968-69 campaign. The weekly or median pH from the 15 samples per week from the three sampling points were categorized by FPI pH range.

The pH drop across the ponds increased as the FPI pH decreased from pH 12.0 to 10.0. The largest pH reductions were experienced when the FPI pH ranged from 8.0 to 10.0. When the FPI pH was from 7.0 to 8.0, it dropped at a slower rate and stabilized at the 6.5-7.0 level.

TABLE 2.--MEDIAN pH, FPI, SPE WEEKLY AVERAGE OF GRAB SAMPLES THREE TIMES PER DAY.

FPI pH range	Number weeks in range	Median pH		
		FPI	SPI	SPE
11.5-12.0	3	11.8	11.6	11.4
11.0-11.5	5	11.1	11.0	10.6
10.0-11.0	1	10.1	10.1	9.4
9.0-10.0	3	9.4	8.8	7.6
8.0- 9.0	2	8.4	7.8	6.8
7.8- 8.0	1	7.4	7.0	6.8

As noted earlier, pH losses in the system were much greater in magnitude and occurred faster when heated flume water was being used, resulting in higher pond temperatures. In most cases, rising pond temperatures resulted in decreasing pH levels.

Higher lime addition (Figure 6, week 15) did not compensate for the influence of heated water on the rate of pH reduction.

Reference was made to a design decision providing for a portion of the water to return from the screens to the flumes without treatment. The percentage of the total flow returned to the flumes without lime addition also correlates with pond pH (Figure 6). When the pond pH was below 10.0, the percentage of untreated return was less than 40 percent. When the pond pH was above 10.0, the return percentage was greater than 40 percent. The ratio of lime addition to water was larger under these conditions.

Although attempted, it was not possible from this study to separate the effects of temperature and return flow percentage on pond pH. In general, high temperatures and low return flow rates seem to be antagonistic to high pH control. Lime addition is most effective when return flow is above the 40 percent level and the flume water is not being heated.

Solids Removal

The suspended and settleable solids that were introduced into the fluming and washing operations consisted of mud, sand, and beet fragments. Some of the heavier solids were removed by the rock drag, which operates in the beet flume. The DSM screens removed an estimated 30 to 50 tons/day of wet material (Figure 7). Therefore, a large percentage of the total suspended solids was removed before liming and before the water entered the first settling pond. However, the water entering the first settling pond, during the 1968-69 campaign, contained an average 56.6 tons of suspended solids per day and the effluent from this pond contained an average of 8.7 tons of suspended solids per day. Thus 47.9 tons of suspended solids settled in the first pond each day for an average 84.6 percent removal. By sedimentation tests it was determined that 94.8 percent of the settleable solids were removed. The fine solids which did not settle readily continued to increase in the recycled waters.

Calculations based on settleable solids analyses showed that the average mud deposition rate in the first pond was about 52,000 gallons (277 yd^3) per day. Since the Longmont factory sliced an average of 3,307 tons of beets per day, 15.7 gallons of first pond capacity was used for every ton of beets sliced. Actual experience during the 1968-69 campaign, involving the amount of time that was required to fill a first settling pond, indicated that this figure is very nearly correct.

Based on the absolute density (Table [illegible] the mud, the total weight of the mud deposited and the total volum[illegible] the mud deposited, the average percent moisture of the deposited mass was 80.7 percent by weight. This wet mud proved difficult to handle during campaign cleaning operations of the first ponds.

This settled mud was removed every three to four weeks during campaign dependent upon the quantity of mud washed from "clean or muddy beets." Only about 85 percent of the mud could be removed from the ponds by clamshell due to the high water content of the mud. After the end of campaign, 100 percent mud removal could be accomplished.

Irregardless of the time of year when mud was removed, it was used as landfill in low areas on the factory premises. This was necessary due to the odors emanating from the mud. A lesser odor problem was encountered from the mud removed from ponds after campaign.

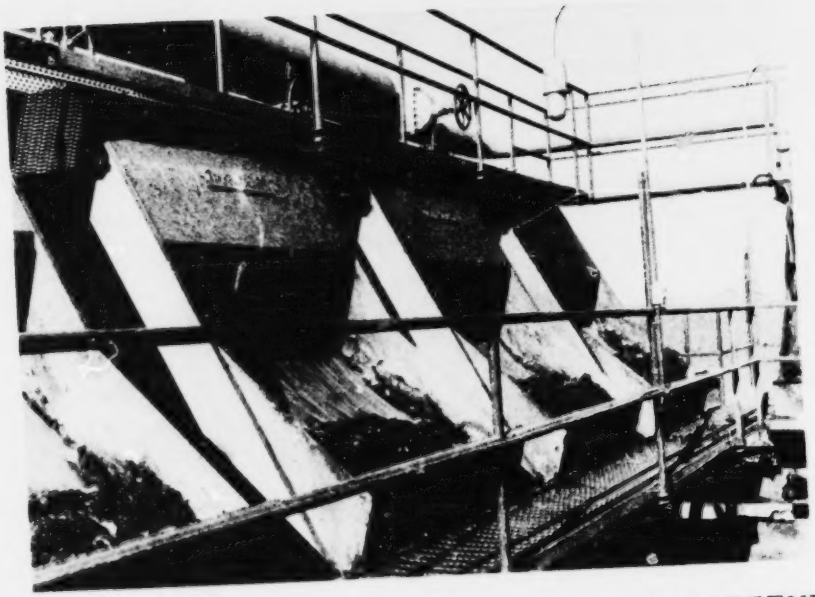

FIGURE 7. TRASH AND SOLIDS REMOVED BY SCREENING.

The moisture in the mud amounted to approximately 48,000 gallons of water per day. This water was lost to the fluming and ponding system and amounted to 1.4 percent of the total pond volume per day. The water loss was, apparently, offset by an inherent increase in system waters.

It was noted that the first pond would maintain a good settling efficiency until it was almost full, at which time settleable solids would begin to carry over into the second pond. The minimum retention time in the first pond to achieve reasonable settling was determined to take between 20 to 30 minutes.

To further characterize the settleable solids in the first pond, the settled mud in one liter of the 24-hour composite sample from the first pond influent was removed daily and composited into weekly samples. These samples were then analyzed (Table 3). The dry mud contained an average of 3.25 percent carbon (the average pH of the diluted sample

TABLE 3.--WEEKLY MUD COMPOSITES, 1968-69 CAMPAIGN AVERAGE.

	Percent on total solids	Average pounds per day
Relative density* 1.366 wet, g/ml		
Absolute density** 2.59 g/ml		
Total CaO	6.36	6,220
Soluble CaO	1.25	1,220
Alkalinity as CaO	0.16	156
Dissolved solids	12.89	12,600
Suspended solids	87.11	85,200
Total solids	100.0	97,800
Total carbon	3.25	3,200

*Relative density based on maximum compacted volume.
**The calculated zero moisture density.

was 8.6). The carbon probably served as a substrate for bacteria and thispH probably did not seriously inhibit bacteriological activity. Thus it is easy to understand why the wet mud produced foul odors when it was being removed from the first ponds.

The average amount of lime addition was 10,440 pounds per day. The amount of total CaO in the dry settled mud averaged 6,220 pounds per day. This means that as much as 59.6 percent of the lime added to the system was lost immediately in the first pond.

The first pond was designed for primary settling of the heavy, more readily settled solids. The second pond was designed to allow more settling time and a milder environment to remove the smaller, more difficult to settle solids. The average amount of solids entering the second pond was 8.7 tons per day. However, the amount of solids leaving the second pond and returning to the fluming operations averaged 9.4 tons per day. This indicated that more insoluble solids were

formed and remained suspended, than were settled in the second pond. The formation of insoluble solids could be accounted for in several ways: sampling analysis; precipitation of insoluble elements; formation of biological sludge; and stirring of the settled sludge by gas evolution from this sludge. The data would indicate that the second settling pond was not performing as expected and could have been excluded from the system, except for its role as a surge basin.

There was evidence of anaerobic biological activity in the first pond as the average amount of organic acids increased by more than 3,000 pounds per day in the pond. This acid production is merely a change in substrate form and may not cause a loss of oxygen demand (22), (Table 4).

TABLE 4.--CHANGE PER DAY ACROSS FIRST AND SECOND PONDS, 1968-69 CAMPAIGN AVERAGE.

	First pond lbs/day	Second pond lbs/day	Total change first pond & second pond lbs/day
BOD_5	- 510*	- 6,390	- 6,900
Soluble CaO	- 40	- 1,100	- 1,140
Total CaO	- 3,570	- 160	- 3,720
Dissolved solids	- 3,250	- 3,210	- 5,560
Total acids (as CaO)	+ 823*	+ 200	+ 1,020
Organic acids (as Acetic acid)	+ 3,410	- 1,450	+ 1,960

*Minus sign indicates loss, and plus sign indicates gain.

An average of only 40 pounds per day of soluble CaO was lost in the first pond but the average amount of total CaO (soluble and insoluble) was reduced by more than 3,000 pounds per day. This indicated that the reduction of CaO in the first pond was due mainly to the settling of insoluble CaO.

The second pond, which had a retention time of approximately 12 hours, reduced the BOD_5 at a rate averaging greater than 6,000 pounds per day. The soluble CaO in the second pond dropped an average of almost 1,100 pounds per day but the total CaO was reduced by only 160 pounds per day. This would indicate that much of the soluble CaO formed insoluble calcium compounds and is probably the source for about 65 percent of the increase in suspended solids upon passage through the second pond.

The formation of insoluble calcium salts might also indicate that some of the BOD_5 reduction in this pond is accomplished by the formation of insoluble calcium-organic acid compounds, as the organic acid and total carbon levels also showed a reduction in this pond. However, bubbling in the pond indicated some complete biodegradation, i.e. carbon substrate → organic acids → methane + CO_2.

Dissolved Solids, COD, BOD in Recirculated Water

The data used in Figures 8 through 10 come from analysis of the second pond effluent (SPE). This point in the system was chosen as the control point.

The concentration of dissolved solids (Figure 8) in the SPE steadily increased as campaign progressed until it reached a peak of about 10,500 ppm during the 14th week. Another investigation (5) of recirculated flume water in the sugarbeet industry has reported a tendency for the dissolved solids concentration to plateau or level off with continued recirculation. The Longmont system showed no positive trend toward leveling off during the 1968-69 campaign.

As Figure 8 indicates, there was a tendency for suspended solids to increase in the SPE as campaign progresses. These suspended solids which carry through the system are very small. For the most part, the quality of the second pond effluent was good from the suspended solids standpoint as values stayed under the 500 ppm level for the first 12 weeks.

The biochemical oxygen demand, chemical oxygen demand and total organic carbon (TOC) concentrations steadily increased until the 13th week of operation (Figure 9). Here again the decrease in concentrations during the 12th week of operation was explained by pond dilution. After the 13th week, the COD, BOD_5 and TOC decreased indicating a high level of biological activity during this period.

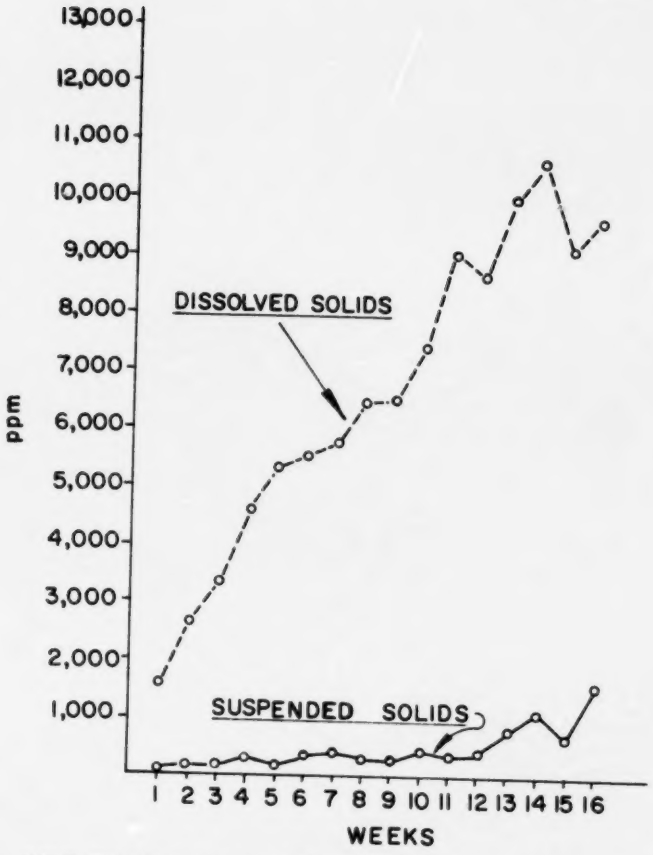

FIGURE 8. SPE INCREASE IN CONCENTRATION OF DISSOLVED AND SUSPENDED SOLIDS DURING CAMPAIGN.

Total sugar concentration in the pond water was dependent on the pH of the water (Figure 10). When the control pH was maintained at a fairly high level the concentration of sugar increased, but when the control pH was low the sugar nearly disappeared resulting in an increase in organic acids. It is noteworthy that, during the 10th week of operation when the control pH fell below 8.0, the total sugars loss was only 1,400 ppm, but the organic acid concentration increased by 3,800 ppm. Operation during this week involved adding heated flume water continuously, and adding 1,000 pounds of lime per hour to the system.

The relationship between control pH, total sugars and organic acid concentrations presents strong evidence that high pH levels inhibit biological

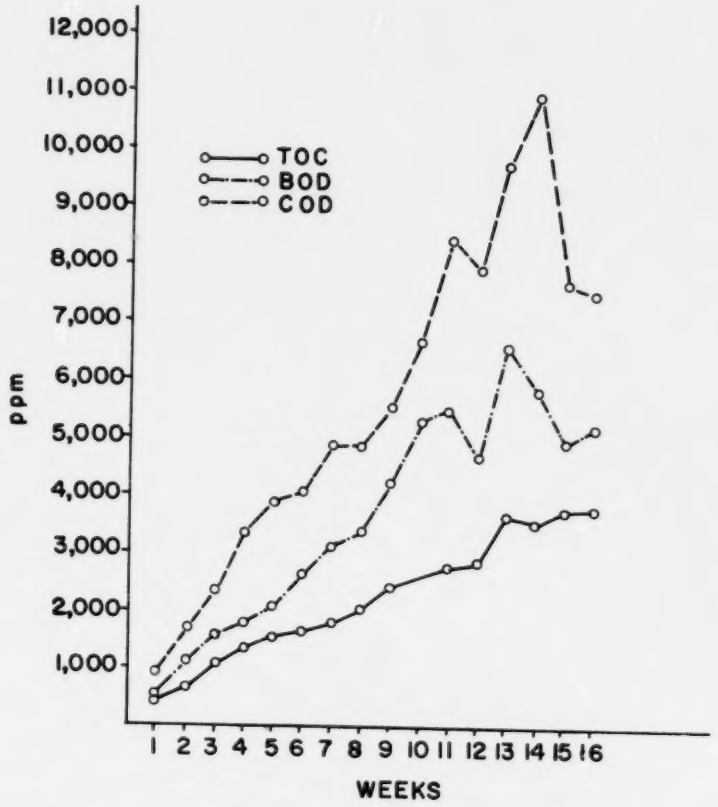

FIGURE 9. SPE INCREASE IN TOC, BOD_5 AND COD DURING CAMPAIGN.

activity and fermentation.

The soluble CaO concentrations increased from 240 ppm to more than 2,600 ppm by the 14th week of operation, and the total acid concentration (calculated as CaO) rose from about 400 ppm to above 3,400 ppm by the 14th week of operation. This indicates that the greater percentage of the soluble cations in the system was calcium.

1967-68 campaign studies (38) indicated that more than 80 percent of the phosphate entering the ponds was removed. It is theorized that phosphate is readily fixed by the soil particles and removed by settling. Under high pH and calcium concentrations, phosphate becomes insoluble and eventually settles out.

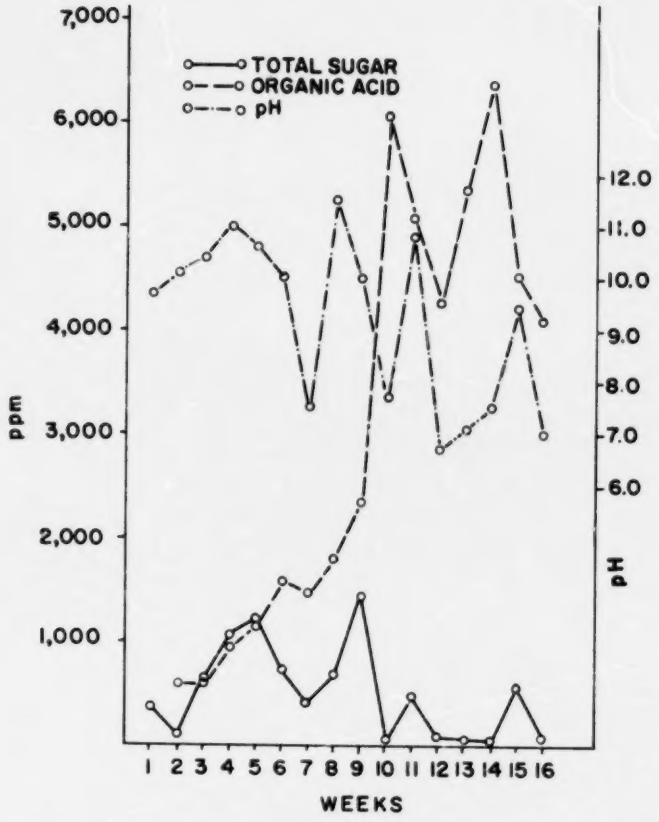

FIGURE 10. SPE RELATIONSHIPS BETWEEN TOTAL SUGARS, ORGANIC ACIDS AND pH DURING CAMPAIGN.

The average concentration of total ortho phosphate in the second pond during the 1968-69 campaign was 4.2 ppm. However, as only a trace of phosphate is necessary to support an active biological population, there was probably enough available phosphate in the system to support biological activity.

Ammonia seemed to be the prevalent form of nitrogen as can be seen from Table 5. Of the total nitrogen, 81 percent was ammonia nitrogen. Ammonia nitrogen increased until the 11th week of campaign reaching a peak of 49ppm after which it steadily decreased. Nitrate and nitrite nitrogen concentrations started above 7.5 ppm and steadily decreased until the 14th week when the concentration levels of these elements were less than 0.5 ppm, where they stayed for the remainder of the campaign.

TABLE 5.--NITROGEN, SULFUR, AND PHOSPHOROUS CONCENTRATIONS, 1968-69 CAMPAIGN.*

	Range ppm		Average ppm	Average pounds in pond
	Maximum	Minimum		
PO_4, total, ortho	9.1	0.4	4.2	99
NO_3-nitrogen	12.0	0.1	3.7	87
NO_2-nitrogen	8.0	0.0	1.8	42
NH_3-nitrogen	50.0	7.0	23.2	546
Sulfate	853	66.0	315	7,410
Sulfite	9.6	1.0	3.6	84
Sulfide	2.0	0.0	0.1	2
Total inorganic nitrogen			28.7	676
Total sulfur			106	2,510

*Combined results on both SPI and SPE.

Sulfate was the predominant sulfur compound in the recirculated flume water. However, anaerobic and faculative bacteria systems can reduce sulfate to the odor producing sulfide state (22). Note that the sulfide concentration was as high as 2.0 ppm, but the average concentration of sulfides was only 0.1 ppm. Odor from the recirculating flume water was noticeable at times but was never a problem during the 1968-69 campaign.

Anaerobic Pond

During the 1967-68 campaign the anaerobic pond was scheduled to receive a 100 gpm flow from the second settling pond and to discharge a flow equal to the influent minus the amount lost to seepage and evaporation. The anaerobic pond was empty at the beginning of the 1967-68 campaign, and during the early part of the season received the prescribed 100 gpm

influent. However, the decision was reached to fill the anaerobic pond rapidly in order to provide a supply of oxygen-demanding waste with which to initiate anaerobic activity. The control by-pass valve was opened to fill the pond rapidly, thus eliminating an opportunity to accurately measure the influent flow.

Following filling, evidence of expected bio-degradation was absent. About 2,000 gallons of domestic sewage secondary sludge were added to the anaerobic pond as inoculum to increase the digestion rate. The results were quite negative; no activity was noted until the end of the campaign.

Two five horsepower surface aerators (Aqua-Lator FLTM-5-4, Wells Product Corporation) with complete anti-erosion assemblies were used in the anaerobic pond. The purpose of the aerators was to spread a layer of oxygenated water across the surface of the pond in order to oxidize evolving sulfides and other elements of the anaerobic digestion process, thus reducing odors. Any reduction in oxygen demand accomplished by these aerators was expected to be a fringe benefit as the pond was not designed to be an aerobic facility.

During both campaigns the aerators worked reasonably well. Odors from the pond were not excessive except during a period of high sulfide liberation. This period lasted about 3 months. Near-zero weather did not hamper aerator operation even though most of the pond surface was ice-covered.

Some foam accumulated on the anaerobic pond from time to time, and mounds of frozen foam piled around the aerators during the periods of zero and sub-zero temperatures. A large build-up of foam was noted at the Parshall flume during the 1967-68 periods of discharge.

Table 6 shows the range and mean of the analysis of the anaerobic pond effluent during the 1967-68 campaign. The results of the anaerobic pond experiences during the 1967-68 campaign suggested that the original concept of an anaerobic pond as a campaign treatment facility would need re-evaluation prior to the next period of operation. As a result, the following decisions were made:

1. To eliminate the anaerobic pond effluent during campaigns so as to hold all of the flume water in the pond system until such a time as this water was sufficiently degraded and acceptable for discharge to the river;

2. To utilize the anaerobic pond as a holding basin which would receive any excess water which might build-up in the settling pond system;

3. To utilize the water residing in the anaerobic pond as a source of make-up to the fluming and settling systems whenever needed.

The data will show that the 1967-68 post campaign water had been successfully treated to meet discharge standards. Prior to the beginning of the 1968-69 campaign the anaerobic pond level was lowered to a water depth of 8 feet. At this level the pond functioned as a reservoir to receive excess flume water with enough capacity to hold all of the expected excess water. Additionally, a carry-over of active seed and sludge was desirable.

TABLE 6.--ANAEROBIC POND EFFLUENT, 1967-68 CAMPAIGN

	Range*			Average lbs/day discharge
	High	Low	Mean	
pH	7.4	6.7		
Total organic carbon	460	245	370	383
Filtered total organic carbon	429	190	344	356
Total CaO	511	365	395	409
Ammonia nitrogen	17.0	2.4	11.5	11.9
Phosphate	0.4	0.0	0.2	0.2
5-day biochemical oxygen demand	1,190	550	750	777
Chemical oxygen demand	1,110	490	762	780
Suspended solids	158	52	100	104
Volatile suspended solids	142	28	81	84
Dissolved solids	1,920	1,400	1,640	1,700
Volatile dissolved solids	870	450	650	670
Settleable solids % by volume	.03	0.0	.01	
Temperature °C	6.0	3.0	4.0	
Flow gpm	171	16	86	

*ppm unless otherwise noted.

The anaerobic pond during the 1968-69 operating season successively served as a surge reservoir for excess second pond water and as a source of make-up water to the fluming system. No serious problems were encountered. The flow pattern permitted an occasional feeding of organic matter into the anaerobic pond. This was accomplished by drawing water from the anaerobic pond into the flumes, which would eventually cause the second settling pond to discharge into the anaerobic pond. This recirculation procedure was employed several times in order to increase the level of oxygen demanding substances in the anaerobic pond for the purpose of maintaining continuing bioactivity.

As the 1968-69 campaign progressed the anaerobic pond temperature steadily decreased. During the ninth week this temperature dropped below 4°C and remained below for the rest of the campaign. The low pond temperature (mean 6°C) probably inhibited biological activity as little reduction in organics was measured during the 1968-69 campaign (Table 7).

The pH of the anaerobic pond varied only slightly. It was highest before any load had been added. When loaded the pH fell to about 7.0-7.5 and changed only slightly after that (Table 9).

The total sugars were mostly degradated to organic acids by the time the water reached the anaerobic pond. A small concentration of sugar persisted, but it is believed that these are carbohydrate forms that are difficult to degrade.

Some of the finer suspended solids carried through to the anaerobic pond. Theoretically, this is good since the fine particles may provide an inert nucleus for growth of biological flocs (36). Sulfides were produced in the pond from time to time, but the average concentration was only 0.2 ppm. The almost negligible odor was also evidence of low sulfide production.

TABLE 7.--ORGANIC DEGRADATION IN ANAEROBIC POND, 1968-69 CAMPAIGN.

	lb in pond end campaign minus begin campaign	lb loaded	lb discharge to flumes	lb degraded
	A	B	C	(B-C) - A
BOD_5	60,000	105,000	43,000	5,000
COD	97,000	175,000	65,000	13,000

TABLE 8.--ANAEROBIC POND DURING CAMPAIGN, 1968-69 CAMPAIGN AVERAGE.

	ppm		
	High	Low	Mean
pH	8.4	6.9	7.6
Total sugar, sucrose	160	0	62
Suspended solids	421	8	156
Dissolved oxygen	9.2	0	1.2
Ammonia-nitrogen	33	5	10.0
Ortho phosphate	2.7	0	0.9
Nitrate-nitrogen	2.5	0	0.6
Nitrite-nitrogen	0.1	0	0.01
Sulfate	676	321	399
Sulfite	9.15	1.1	2.8
Sulfide	1.1	0	0.2

When the fluming operations ceased, the water in the first and second ponds was discharged to the anaerobic pond for biodegradation after both the 1967-68 and 1968-69 campaigns. The results from these two years have not been combined, but were similar. The data from 1968-69 are reported below in detail with occasional reference to 1967-68 treatment.

After the end of beet fluming in January 1969, the first and second settling pond water was recirculated through an evaporator-condenser (CSF) for one week prior to its discharge into the anaerobic pond. This was done to increase the temperature of the fluming water before its discharge into the cold environment of the anaerobic pond so as to increase the bioactivity in the fluming water and thus accelerate the rate of degradation. The settling pond temperature during this period of recirculation was maintained at about 30°C. After the heating and recirculation period the first and second settling pond water was pumped to the anaerobic pond. The pond level had been kept low enough to re-

ceive all of the water from the settling system so there was no resulting discharge.

The water remained in the anaerobic pond until mid-September, 1969. At that time the biological stabilization of the organics was nearly complete and pond contents were subsequently used to fill the flumes for the 1969-70 campaign.

The two 5-hp aerators ran continuously (except for short periods of mechanical failure and planned experimental shut-downs) until the last week of July, when a high concentration of algae was noted. The aerators remained off until the last week in August, at which time mechanical aeration was resumed.

Phosphate was added to the pond six times during the post-campaign period to accelerate biological activity since the phosphate analysis indicated a deficiency for optimum activity. The first two additions of phosphate were in the form of triple super phosphate, a granular commercial fertilizer containing 46 percent P_2O_5. However, the granular material dissolved slowly and all subsequent additions were in the form of ammonium phosphate, a liquid commercial fertilizer with a 10 percent ammonia nitrogen and 34 percent P_2O_5 analysis. The liquid addition proved to be satisfactory; adequate levels of soluble ortho phosphate were achieved.

After the campaign of 1968-69, the anaerobic pond was sampled in the same manner as during the 1967-68 post-campaign period, except that the samples were composited by depth in an attempt to explore the possibility of stratification. This sampling procedure was continued for the first 8 weeks of the post-campaign period. From the data it was determined that stratification did not exist in the pond and that extensive sampling was not necessary for depth differences. Table 30 in the appendix shows the analytical schedule which was conducted on the anaerobic pond samples for the first 8 weeks of the post-campaign period (February 3 to March 28, 1969).

Beginning with the 9th week of the post-campaign period, the anaerobic pond was sampled as described above. However, all samples were composited. Table 31 in the appendix shows the analytical schedule performed until July 9, 1969, and Table 32 shows the analytical schedule continued thereafter.

On February 5, 1969, the anaerobic pond was at a depth of 11' 4" and contained more than 145,000 pounds of BOD_5. Under conditions of high

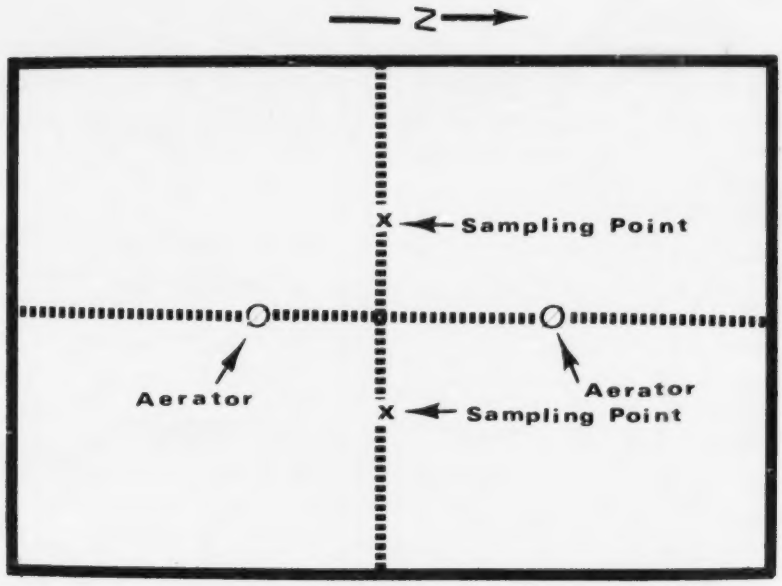

FIGURE 11. ANAEROBIC POND SAMPLING POINTS AFTER CAMPAIGN, SAMPLED AT DEPTHS OF 3, 6, 9, AND 12 FEET.

temperature the water quickly became very black and remained this color until mid-May when it slowly began to clarify. Addition of this heated water to the water in the anaerobic pond raised the average pond temperature to above 6°C but cooled to 4°C one week later (Figure 12). The pond temperature remained low until the 8th week, after which natural ambient heating gradually raised the temperature to a peak of 25°C.

During the period in which the pond temperatures were 15°C or less (from the 1st to the 13th week) the rate of reduction in oxygen-demanding substances was low compared to the period in which pond temperatures ranged between 15 and 25°C (Figures 12 and 13). This indicated that temperatures above 15°C, together with ample phosphate addition, provided a more favorable environment for biological degradation (Tables 9 and 10).

There are some interesting comparisons to be made between the 1967-68 and the 1968-69 post-campaign performance of the anaerobic pond. The 1967-68 BOD_5 loading was 27,000 pounds compared with 147,000

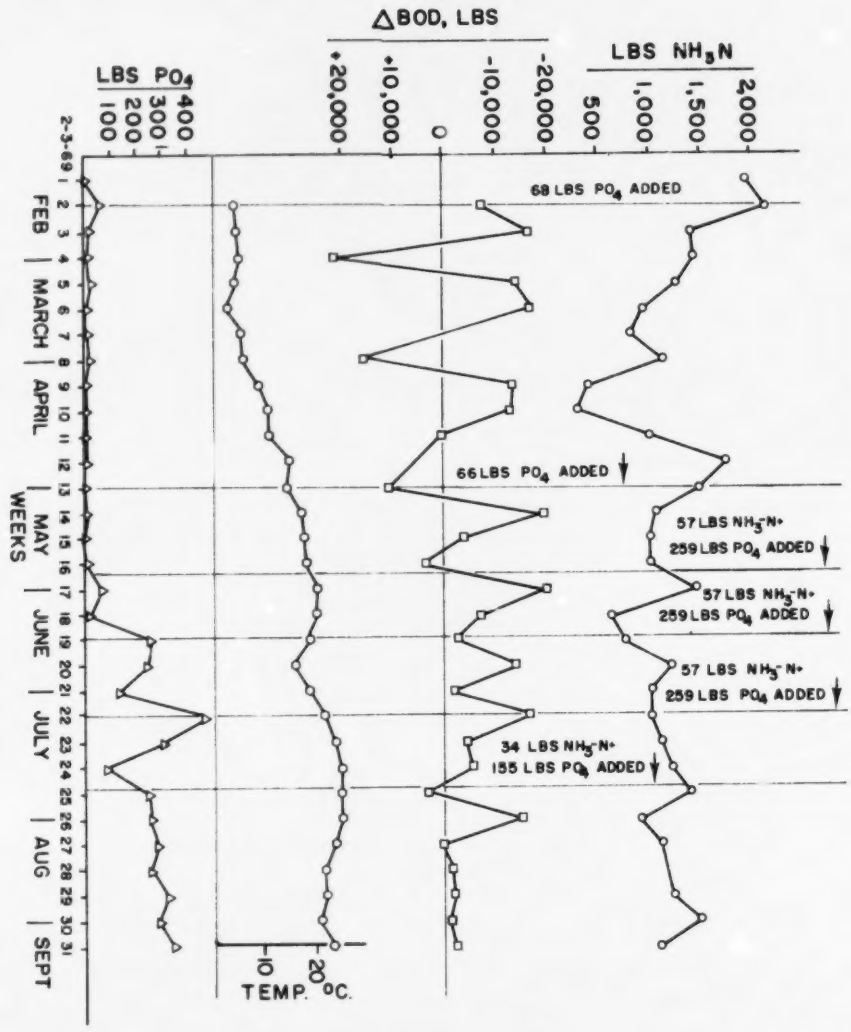

FIGURE 12. EFFECT OF NUTRIENT ADDITION AND THE N-P_2O_5 ANALYSIS ON RATE OF BOD_5 REDUCTION. THE WATER TEMPERATURE RELATION IS ALSO SHOWN, 1968-69 CAMPAIGN.

pounds in 1968-69. In 1967-68 the temperatures ranged from 3 to 10°C and it took 84 days to complete digestion at an average rate of 321 pounds per day. In 1968-69 the digestion rate was similar during the same periods of time and temperature, but increased to 1,145 pounds/day when temperatures increased to a range between 15-25°C. Although the treatment period in 1968-69 lasted for 217 days, the daily rate of BOD_5 removal averaged 677 pound/day. This was rather conclusive proof of the temperature and nutrient effect on rate of activity. In both years green algae appeared at the 200-300 BOD_5 level and traces of dissolved oxygen were measured.

The curve showing the change in organic acids is irregular; significant

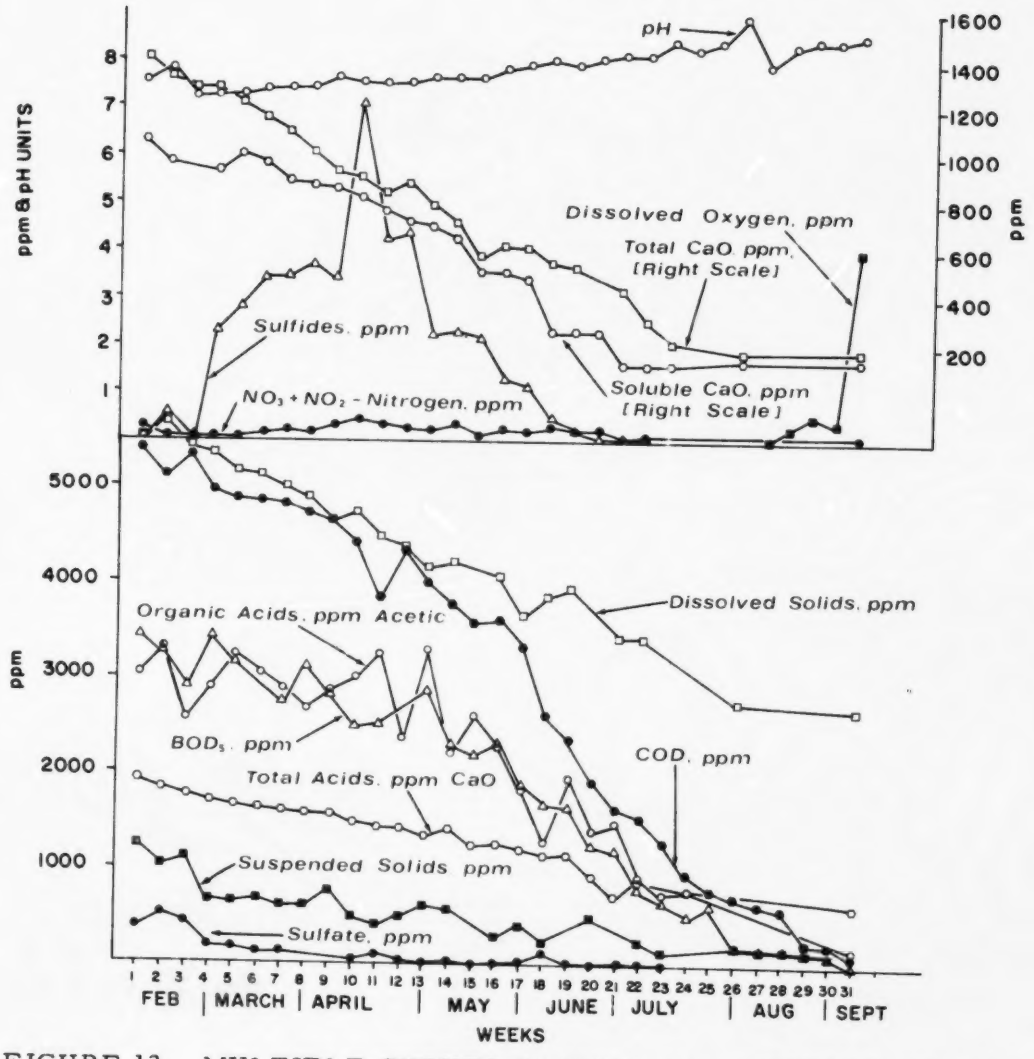

FIGURE 13. MULTIPLE CURVES SHOWING THE AVERAGE WEEKLY ANALYSIS DURING THE POST-CAMPAIGN PERIOD OF 7 MONTHS.

increases and decreases in organic acid levels were noted as time progressed (Figure 13).

TABLE 9.--ANAEROBIC POND; POST CAMPAIGN 1967-68, 1968-69; BOD_5 REDUCTIONS.

	Post campaign 1967-68 1/23 to 4/16/69	Post campaign 1968-69 2/3 to 4/30/69	Post campaign 1968-69 5/7 to 7/30/69
Temperature range C°	3 - 10	3 - 12	15 - 25
Phosphate added* - lbs.	0	68	998
BOD_5 reduced, average lbs/day	321	388	1,145

*Soluble ortho phosphate

The BOD_5 curve was similar to the organic acid curve, (although the cycles showed a different frequency) as the areas under both curves differed by less than 2 percent (calculated from the first to the 24th week). This indicated that most of the BOD_5 in the system could possibly be attributable to organic acids. The COD curve was more constant and not subject to many concentration variations.

The decrease in dissolved solids seemed to follow the COD curve until the 17th week when the two began to diverge. At that point the rate at which dissolved solids were removed became much less than the rate of COD removal. At the 31st week a concentration of nearly 2,700 ppm of dissolved solids remained, probably as mineral salt forms.

Sulfates diminished in the system until the 12th week when they reached a very low level. It is assumed that the facultative and anaerobic organisms utilized sulfate in the production of odor-producing sulfides. The sulfide curve relates inversely with the sulfate curve as the concentration of sulfides increased until the sulfate concentration was at a minimum. The sulfides then dissipated until the 20th week when they disappeared. Odor produced by the sulfides was very distinct during much of the 1968-69 post-campaign period even though the aerators were operating continuously.

Total and soluble CaO continued to be reduced in the anaerobic pond. Their reduction might be explained by the precipitation of insoluble calcium compounds. During the 31-week period more than 56,700 pounds of total CaO was removed of which more than 41,900 pounds was soluble (Table 11). As would be expected from the calcium data, total acids also were reduced by more than 61,500 pounds. Soluble CaO

TABLE 9.--ANAEROBIC POND; POST CAMPAIGN 1967-68, 1968-69; BOD_5 REDUCTIONS.

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TABLE 10.--ANAEROBIC POND; SEPTEMBER 23, 1969; FINAL ANALYSIS AND TOTAL REDUCTIONS FOR 1968-69 POST CAMPAIGN PERIOD.

	ppm	Lbs in pond 2/5/69	Lbs in pond 9/3/69	Reduction lbs	Reduction %
pH (pH units)	8.5				
BOD_5	31	148,000	1,000	147,000	99
COD	87	229,000	2,700	226,000	99
Dissolved oxygen	4.0	0			
Suspended solids - total*	80	53,500	2,400	51,100	95
Dissolved solids - total**	2,700	234,200	82,000	152,000	65
Organic acids (as acetic)	150	129,000	4,600	124,000	96
Total acids (as CaO)	631	81,000	19,300	61,600	76
Nitrogen - ammonia	36	2,000	1,100	?	?
Sulfate	0	16,200	0	16,200	100
Sulfide	0				
Phosphate (soluble, ortho)	11.2	0	343		
Total CaO	386	69,000	12,000	57,000	83
Sol CaO	354	52,800	10,800	42,000	79
Volume, gallons		43×10^6	31×10^6	12×10^6	29

*100 percent volatile
** 45 percent volatile

charge of phosphate-containing water to receiving waterways is restricted in some areas. It is apparent that phosphate addition must be handled with care. It is, therefore, recommended that no phosphate be added to a flume water waste pond after the BOD_5 has been reduced to below the 200-300 ppm level.

The coliform levels in the pond fell to near zero in early March and remained quite low (Table 12). The fecal streptococci varied from test period to test period. However, fecal strep levels also were quite low varying from 0 to 300 per ml.

The total counts of both aerobes and anaerobes remained fairly constant at a level of about 10^6 to 10^7 per ml, until July when the numbers dropped slightly. The close similarity between anaerobic and aerobic counts indicates that the anaerobic pond was not anaerobic but was facultative during the entire period of digestion. The predominant organism in the pond was of the genus Leuconostoc, which is a facultative organism. The sugar industry, both beet and cane, has encountered this organism in its processing procedures in the past.

TABLE 11. BACTERIA COUNTS (WEEKLY AVERAGE) AND POND AERATION; ANAEROBIC POND 1967-68 POST CAMPAIGN.

Date	Week number	Coliform MPN/ml	Fecal Streptococci MPN/ml	Total aerobic 10^6MPN/ml	Total anaerobic 10^6MPN/ml	Aerator horsepower hours
Feb 3 + Feb 5	1	21	302	38	30	240
Feb 10 + Feb 12	2	43	202	32	40	1,040
Feb 17 + Feb 19	3	26	100	69	22	1,320
Feb 24 + Feb 26	4	30	52	28	44	240
Mar 3 + Mar 6	5	5	56	56	131	600
Mar 10 + Mar 12	6	7	3	87	159	810
Mar 17 + Mar 19	7	6	142	36	46	1,130
Mar 26	8	4	118	20	54	1,055
April 2	9	0	88	53	42	1,680
April 9	10	0		66	65	1,680
April 16	11	0		32	57	1,680
April 23	12	0		64	56	1,680
April 30	13	6		66	53	1,680
May 7	14	2	6	55	36	1,680
May 14	15	4	2	48	49	1,680
May 22	16	2	1	31	39	1,680
May 28	17	3	30	3	50	1,680
June 6	18	4	0	7,300	136	1,440
June 11	19	6	4	24	14	1,680
June 18	20	1	96	7	33	1,680
	21					1,680

TABLE 11.--(continued)

Date	Week number	Coliform MPN/ml	Fecal Streptococci MPN/ml	Total aerobic 10^6MPN/ml	Total anaerobic 10^6MPN/ml	Aerator horsepower hours
July 1	22	0	8	0.4	0.1	1,680
July 9	23	1	23	0.3	0.4	1,680
	24					1,680
	25					1,680
July 30	26	84	120	0.4	0.1	1,520
		55	30	1.2	6.1	
Aug 6	27					0
Aug 13	28					0
Aug 20	29					0
Aug 27	30					0
Sept 3	31					1,665

SECTION VII

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SECTION VIII

APPENDIX I

TABLES

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ANALYSIS OF DATA

Chemical Analysis

All of the acquired data were punched for computer evaluation. The computer program was developed to compare separate variables with each of the other variables on a straight mathematical basis. Bacteria numbers, however, were plotted using the $\log_{10}$ numbers because of extreme variations.

Correlations above .70 were considered to be valid, but some coefficients below this level appear in the tables because of the possibility of multiple factor influences. Correlations established for the FPI, SPI and SPE are shown in Tables 12, 13 and 14.

The correlation of the variables with "Date" indicates the degree of predictability of the concentration build-up with respect to time. There were no valid date correlations during the 1967-68 campaign since the system was not in hydraulic balance.

Total sugars did not correlate well with any of the other elements during the 1968-69 campaign, and only slightly with total CaO, soluble CaO and pH. During the 1967-68 campaign total sugar correlated well with alkalinity (Table 13) and when combined with soluble CaO-alkalinity (a measure of organic acids) correlated well with BOD_5, COD and TOC. This would indicate that a large percentage of the organic oxygen demand comes from the sugar.

Total CaO and soluble CaO correlated well with each other during 1968-69, and also with BOD, COD, TOC and pH. During 1967-68total and soluble CaO correlated with each other and with BOD_5. This is an indication that the amount of insoluble CaO (total CaO-soluble CaO) in the system is predictable; that a neutralization reaction occurs between the lime added and the organic acids produced; there is no explanation for the negative correlation between CaO and pH.

BOD_5, COD and TOC correlated with each other well during the 1967-68 campaign, and these correlations were again well established during the 1968-69 campaign. It is noteworthy that during both years the BOD_5-TOC correlation became better as the flow progressed from first pond influent to second pond effluent. It is theorized that this phenomenon is due to the fact that the fine organic solids which probably have an oxygen demand different from an equivalent concentration of dissolved organic compounds settled as the flow progressed through the ponds, and this settling increased the predictability of BOD_5 from TOC data.

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TABLE 12.--FIRST POND INFLUENT CORRELATION COEFFICIENTS; 1967-68 CAMPAIGN.

	Sol. CaO	BOD_5	COD	pH	TOC	Filt. TOC	TS	TVS	SS	DS
Total acids	.72				.75	.72				
Sol Ca0-Alk.	.98									
COD		.74								
TOC		.74	.82				.69	.80		.68
Filt. TOC		.74	.78		.96					
Alkalinity				.73						
PO_4					.70	.73				
TVS							.80			
SS							.85			
VDS		.66	.72		.86		.71	.93		.78
Sett. Sol.							.86		.82	
DS								.71		
Sol Ca0-Alk. & tot. sug.		.64	.60		.69					
COD-TOC+ BOD_5			.94							
TOC and NH -N		.69								

TABLE 13.--SECOND POND EFFLUENT CORRELATION COEFFICIENTS; 1967-68 CAMPAIGN

	Sol CaO	BOD_5	pH	TOC	TS	TVS	SS	DS	Tot sug	Tot CaO	COD
BOD_5	.80				.71	.76		.68		.79	
Sol AaO-Alk	.996	.76								.80	
Tot. acids	.90	.80									
COD		.75			.70	.81		.70			
TOC		.83			.76	.89		.75			.88
Filt. TOC		.83		.98							.85
Alkalinity			.83						.79		
DS					.99	.80					
VDS		.74		.90	.80	.99		.80			.81
TVS					.81						
Sett. Sol.							.77				
Sol. CaO										.80	
Sol. CaO-Alk & tot. sug.		.85		.83							.75
COD-TOC+ BOD_5											.89
TOC & NH_3 -N		.75									

TABLE 14.--CORRELATION COEFFICIENTS, RECIRCULATED FLUME WATER SYSTEM, LONGMONT FACTORY, 1968-69.

Correlation	First pond influent	Second pond influent	Second pond effluent
1. Date and			
Total CaO	.870	.902	.892
Soluble CaO	.906	.905	.907
BOD_5	.882	.860	.902
COD	.904	.886	.900
pH	-.561	-.442	-.457
Total carbon	.922	.918	.951
Control pH			.548
2. Total sugars and			
Total CaO	-.456	-.440	-.422
Soluble CaO	-.485	-.403	-.452
pH	.556	.551	.554
3. Total CaO and			
Soluble CaO	.964	.969	.950
BOD_5	.949	.930	.919
COD	.935	.937	.935
pH	-.463	-.416	-.405
TOC	.859	.928	.978
4. Soluble CaO and			
BOD_5	.936	.951	.926
COD	.942	.970	.951
pH	-.526	-.439	-.443
Total carbon	.893	.921	.980
5. BOD_5 and			
COD	.934	.926	.920
pH	-.492	-.377	-.408
Total carbon	.787	.844	.964
6. COD and			
pH	-.540	-.422	-.431
Total carbon	.940	.923	.980

TABLE 14.--(continued)

Correlation	First pond influent	Second pond influent	Second pond effluent
7. pH and			
Total carbon	-.698	-.433	-.410
Alkalinity	.752	.792	.797
8. Total carbon and			
Total acids	.151	-.403	-.301
9. Date and			
Total solids	.846	.910	.924
Suspended solids	.530	.645	.693
Dissolved solids	.896	.888	.910
Settleable solids	.548	.377	.363
10. Total solids and			
Suspended solids	.834	.646	.689
Dissolved solids	.917	.993	.992
11. Suspended solids and			
Dissolved solids	.545	.553	.596
Settleable solids	.913	.779	.845
12. Dissolved slids and settleable solids	.552	.411	.258
13. Recirculation rate and			
Control pH	.602		
Lime addition	-.475		

Volatile solids correlated well with the total solids during 1968-69 and with BOD, COD, and TOC. This is due to the carbonaceous nature of a large percentage of the volatile solids.

Tables 15 and 16 relate to the anaerobic pond during campaign. During the 1967-68 campaign the anaerobic pond produced very few valid correlations, but during the 1968-69 campaign many significant correlations were obtained. It is interesting to note that most of the correlations established

TABLE 15.--CORRELATION COEFFICIENTS; ANAEROBIC POND DURING CAMPAIGN; LONGMONT FACTORY; 1968-69.

	Date	pH	BOD_5	COD	Sol. Cao	Tot CaO	Tot Sug	TS	SS	DS	Tot Acids	Org Acids	Temp
pH	-.55												
BOD_5	-.92	-.53											
COD	.91	-.57	.94										
Sol. CaO	.88	-.44	.90	.92									
Tot. CaO	.92		.89	.89	.94								
Tot Sug		-.47											
TS	.93	-.53	.95	.98		.91							
SS	.48		.71	.70	.66	.57		.72					
DS	.95	-.48	.94	.97	.92	.92		.99	.62				
TS	.91		.86	.91	.89	.87		.92	.55	.94			
Org Acids	.91		.88	.92	.88	.88		.92	.50	.94	.90		
Temp	-.55		-.82		-.75								
Tot carbon	.94		.94	.96	.97	.94	.56	.98	.76	.97	.89	.86	-.97
Dissolved O_2	-.70	.75	.63	-.73		.76		-.64	-.69	-.73	-.55	-.86	
Ammonia nitrogen			.55	.67	.56	.52		.67	.82	.58	.43	.49	

TABLE 16. CORRELATION COEFFICIENTS FROM ANAEROBIC POND; 1967-68 CAMPAIGN.

	TS	TVS	SS	DS	Filt. TOC	COD
TVS	.97					
DS	.99	.95				
VDS	.96	.98		.97		
VSS			.95			
TOC					.72	.71

in the first and second ponds carried through to the anaerobic pond where a semi-stagnant concentration of organic acids correlated with BOD_5. However, a valid BOD_5 to organic acid ratio was not established in the settling pond system. This is possibly due to settling of the insoluble organic acid salts in the static environment of the anaerobic pond and incomplete settling of these salts in the turbulant environment of the re-circulated water.

Biological Analysis

During campaign, grab samples were taken of the second pond influent, second pond effluent and anaerobic pond and analyzed biologically. The data show that both coliform and fecal streptococci increased as campaign progressed at both the secondary pond influent and effluent (Table 17). and Table 18).

This was probably due to a constant input of these organisms from beet washing and from recycling of second pond water. This would offset death of the organisms that could be expected from the lime treatment. The total aerobic and anaerobic counts also increased but slower than the indicator organisms as campaign progressed. This would be due to one of several factors: death of the organisms and precipitation in the lime-treated primary system are removing more of these general microbial forms; also many of these organisms could be forming clumps which do not give a true plate count in the laboratory.

The increase for both the total counts and the indicator organisms are greater at the influent than at the effluent. This would indicate that some of these organisms are being removed in the second pond. The removal of total anaerobic bacteria and coliform are more effective than the removal of total aerobic bacteria and fecal streptococci.

At the second pond influent the very high negative correlation seen between the date line and NO_3-NO_2 nitrogen (Table 17) indicates that even in the short exposure time of the primary system, microbial breakdown of these nitrogenous substrates is initiated. This is supported by the slight increase in NO_2-N seen as time progressed.

With only five observations at the second pond influent streptococci and coliforms correlated at 78 percent. Coliforms and total aerobic and anaerobic counts only correlated at about 60 and 54 percent, respectively, while fecal streptococci and total counts correlated at 72 and 71 percent with 17 observations. As waste load increased, as shown by COD and BOD readings, the coliform counts increased with a fair correlation. Similar correlation between streptococci and COD and BOD occurred. (Poorer (50-60 percent) correlation between total aerobic and anaerobic counts and waste was observed.)

The coliform correlations seem to be due to the direct relationship of the organisms to total acids and organic acids which were increased and to NO_3-NO_2N which decreased; but not related to NH_3-N. Similarly, total organic carbon rose parallel to the coliforms. Also, fecal streptococci correlated in a similar manner with total acids and organic acids and with decreasing NO_3-NO_2N. Excellent correlation to TOC was seen. The total aerobic bacteria correlations to these same factors were poor, as were the anaerobic count correlations. This is due to the very diverse metabolic activities of these organisms. It should be noted that the correlation between total aerobic and anaerobic bacteria is excellent, probably due to the fact that in both groups we are really chiefly measuring the number of facultative organisms.

The BOD and COD levels correlate almost perfectly, and with the indication that BOD correlates with total acids, organic acids, NO_3 and NO_2N and even with ammonia-N, there is evidence the waste load is almost exclusively organic material rather than inorganic salts. This is also seen in the TOC vs. BOD correlation and also with the COD correlations with the same factors.

In the observations of each organisms group counted there is further evidence that counts drop as pH rises. Only the streptococci seem to show

a correlation of significance (77 percent).

The pH vs. TOC correlation of -74 percent further emphasizes the critical nature of the pH of the system for the control of micro-organisms by increasing pH.

Coliforms and fecal streptococci rose in a parallel manner but again did not correlate as well with the total counts. The aerobic and anaerobic total counts rose with a good degree of correlation, again pointing to the facultative nature of the system. The coliforms increased similarly as the BOD and TOC while the streptococci correlated to a lesser degree, and total aerobic and anaerobic bacteria correlated poorly. The coliforms agree well with total acids but to a marginal degree with organic acids. Fecal streptococci seem to be better related to these acid measurements, but total counts seem completely unrelated even though they are present in far greater numbers than the indicator organisms.

Coliforms do relate well with total organic carbon and less with NO_3-N. Both coliforms and fecal streptococci show the expected drop as pH rises, but the total counts show no relationship to pH.

In the second pond no other discernable biological relations are detectable. This probably is due to the temperature, pH and short retention time. Some biological activity is evident; however, this portion of the system seems to be an acclimatization zone for the organisms. Also, the recycling of water back to the flumes has a continuing input of new materials, both biological and chemical.

In the anaerobic pond, relatively few coliforms were found, and the numbers did not vary greatly during campaign--ranging from about 10 to 1,000/ml in 1968-69 and less than 100 in 1967-68. Fecal streptococci were about 10 times as numerous as coliforms and did increase as the campaign progressed. Again, this indicates the greater survival power that fecal streptococci have over coliform. Aerobic and anaerobic counts were quite a bit more numerous, as expected, but did not vary in relation to time with any correlation. Mean numbers were over 10^6 organisms/ml.

As at the other sampling points, COD and BOD correlated with time and with each other (Table 19). As in the primary-secondary pond system, there is good indication that the BOD as well as COD consists of biodegradable materials. In this biologically active unit, ammonia-N does correlate fairly well with time while the NO_3-NO_2N scatters randomly. Also, the TOC-date correlation is almost perfect, indicating

TABLE 17. CORRELATION COEFFICIENTS; SECOND POND INFLUENT SAMPLES TAKEN FOR BIOLOGICAL AND CHEMICAL ANALYSIS; 1968-69 CAMPAIGN

	Date	Coliform	Fecal strep	Total aerobic	Total anaerobic	pH	BOD_5	COD	Phosphate	Total acids	Organic acids	NO_3+NO_2-N	NO_2-N	NH_3-N	Sulfate	Sulfite	Sulfide
Coliform	.83																
Fecal strep		.78															
Total aerobic		.60	.72														
Total anaerobic		.54	.71	-.60	-.65												
pH	-.68	-.54	-.78	-.60													
BOD_5	.93	.82	.80			-.68											
COD	.85	.75	.66			-.62	.88										
Phosphate						-.65											
Tot. acids	.86	.80	.75			-.63	.91	.91									
Organic acids		.85	.81			-.59	.91	.86		.97							
NO_3+NO_2-N	-.91	-.79	-.76			-.66	-.89	-.84		-.88	-.85						
NO_2-N	-.87		-.66				-.89	-.76		-.86	-.74	.96					
NH_3-N							.69	.69			.69	-.55	-.65				
Sulfite	.79		.86		.62		.72			.63	.72	-.64	.57				
Sulfide	-.86								-.71	-.73	-.65	.96		-.56	.65	.84	.83
Tot. carbon	-.98	.87	.91			-.74	.97	.81			.94	-.94	-.91				
Tot. sugar		-.49	-.43	-.35						-.76	-.73	.68					

TABLE 18.--CORRELATION COEFFICIENTS: SECOND POND EFFLUENT SAMPLES TAKEN FOR BIOLOGICAL AND CHEMICAL ANALYSIS;1968-69 CAMPAIGN.

	Date	Coliform	Fecal strep	Total aerobic	Total anaerobic	pH	BOD_5	COD	Phosphate	Total acids	Organic acids	NO_3+NO_2-N	NO_2-N	NH_3-N	Sulfate	Sulfite	Total carbon
Coliform	.83	.															
Fecal strep	.80	.84															
Total aerobic		.75															
Total anaerobic		.62		.86													
pH	-.67	-.80	-.91	-.58	-.43												
BOD_5	.91	.76	.66														
COD	.88	.74	.72				.93										
Phosphate			.69														
Total acids	.87	.80	.79				.93										
Organic acids	.81	.67	.76				.94			.96							
NO_3+NO_2-N	-.89	-.76	-.81			-.71	-.82	-.81		-.88	-.83						
NO_2-N	-.87	-.71	-.79				-.79	-.67		-.84	-.79	.93					
NH_3-N							.66				.70	-.48	-.60				
Sulfate			-.67	-.51			.72										
Sulfite	.83	.67	.93	-.52				-.73		.74	.69	-.71	-.68				
Sulfide		.90	.99					.70	.91	.66	.67	-.56	-.91	.66	.66		
Tot. carbon	.91	.86	.80			-.71	.98	.98		.98	.97	-.85	-.80			.78	
Tot. sugar		-.70	-.80	-.50						-.70	-.67	.67					-.79

TABLE 19.--CORRELATION COEFFICIENTS; ANAEROBIC POND SAMPLES TAKEN FOR BIOLOGICAL AND CHEMICAL ANALYSIS; 1968-69 CAMPAIGN.

	Date	Coliform	Fecal strep	Total aerobic	Total anaerobic	pH	BOD_5	COD	Phosphate	Total acids	Organic acids	NO_3+NO_2-N	NO_2-N	NH_3-N	Sulfate	Sulfite
Coliform																
Fecal strep	.75															
Total aerobic																
Total anaerobic				.91												
pH	-.63			-.85	-.70											
BOD_5	.95		.71		-.61											
COD	.94		.75		-.69		.97									
Phosphate	.75		.75				.67	.73								
Tot.acids	.90		.79				.90	.93	.80							
Organic acids	.94		.82													
NO_3+NO_2-N		-.53					.91	.94	.77	.94						
NO_2-N							-.63									
NH_3-N	.76															
Sulfate		-.66					.77	.81		.68	.76					
Sulfite	.77		.69								.64					
Sulfide							.81	.86		.81	.87					
Tot.carbon	.97		.80		-.57		.98	.98	.81	.96	.96	-.60		.76		
Temp.	-.93	-.71		-.69	-.70		-.97	-.94		-.75		-.71		.76		.85
Tot.sugar					.72									-.80		-.71

the degradability of the waste and the low concentrations of COD-producing salts of minerals.

A 5-6° decrease in water temperature during campaign had little effect on the biological action.

While coliforms did not correlate with any of the physical and chemical variables, the fecal streptococci did show 70-80 percent correlation with BOD, COD, TOC organic acids, PO_4 and total acids, but not against the nitrogenous materials. It seems that in this pond, as observed previously also, fecal streptococcus is a better index than coliforms if one of the standard pollution indices must be used.

Total aerobic and anaerobic counts correlate very well with each other but with no other parameter except pH and, to some degree, with temperature. Again, we are measuring facultative types of cells.

Phosphate analyses showed low levels in the pond (mean less than 1 mg/liter) with considerable scatter of results. As expected, as the organic and total acids and TOC levels rose, the PO_4 rose also but never to levels over 1.1 mg/liter. This may indicate the limiting effect of the lack of PO_4 on microbial activity allowing build-up of wastes. In this waste the organic acids and total acids seem to be the same and also about the same materials as measured to TOC.

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TABLE 20.--ABBREVIATIONS USED IN THIS REPORT, ALPHABETICAL ORDER.

1.	Alk.	Alkalinity
2.	APE	Anaerobic Pond Effluent
3.	APDC	Anaerobic Pond Depth Composite
4.	APG	Anaerobic Pond Grab
5.	BOD_5	Biochemical Oxygen Demand (5-day)
6.	COD	Chemical Oxygen Demand
7.	CWE	Condensed Water Effluent
8.	DO	Dissolved Oxygen
9.	DS	Dissolved Solids
10.	EHPI	East Holding Pond Influent
11.	Filt. TOC	Filtered Total Organic Carbon
12.	FPI	Filtered Pond Influent
13.	gpm	Gallons per minute
14.	MPN	Most Probable Number
15.	NH_3-N	Ammonia Nitrogen
16.	NO_3-N	Nitrate Nitrogen
17.	NO_2-N	Nitrite Nitrogen
18.	Org. Acids; OA	Organic Acids
19.	PO_4	Soluble Phosphate
20.	PPC	Primary Pond Center
21.	PPE	Primary Pond Effluent (Secondary Pond Influent)
22.	SO_4	Sulfate
23.	SO_3	Sulfite
24.	Sol. CaO	Soluble CaO
25.	SPE	Second Pond Effluent (Anaerobic Pond Influent)
26.	SPI	Secondary Pond Influent
27.	SS	Suspended Solids
28.	S	Sulfide
29.	Suc.	Sucrose
30.	T°C	Temperature Degree in Centigrade
31.	TOC	Total Organic Carbon
32.	Tot. Acids	Total acids/meq./liter
33.	Tot. CaO	Total CaO
34.	Tot. Sug.	Total Sugars
35.	TS	Total Solids
36.	TVS	Total Volatile Solids
37.	VDS	Volatile Dissolved Solids
38.	Vol.	Volume
39.	VSS	Volatile Suspended Solids

TABLE 21.--DESCRIPTION OF ANALYTICAL PROCEDURES.

	Analysis	Description
1.	Total sugars anthrone method	This determination involves mixing 5 ml anthrone H_2SO_4 solution with 1 ml of filtered sample and heating in a boiling water bath for 10 minutes. A color is developed which is proportional to the amount of sugar present. The absorbancy of this color is read on a colorimeter, and by comparison with the graph of the absorbancy standard, sucrose can be determined.
2.	Total CaO	The method employed for this determination involves mixing a measured volume of sample with enough concentrated HCl to dissolve all of the insoluble calcium and diluting to a known volume. An alequot is then titrated with standard versenate solution to the Univer I end point.
3.	Soluble CaO	In this determination a sample was filtered, and an alequot was titrated to the Univer I end point with standard versenate solution.
4.	Biochemical oxygen demand	The procedure described in "Standard Methods for the Treatment of Water and Waste Water," 12th edition, was utilized.
5.	Chemical oxygen demand	The procedure utilized in this determination is described in "Standard Methods of the Treatment of Water and Waste Water," 12th edition, except that the end product was read colorimetrically in a Hach DR Colorimeter, Model 1104, rather than titrated. During 1968-69 the results were determined by titration.
6.	pH	pHs were read directly on a Leeds and Northrup pH meter.

TABLE 21.--(continued)

7.	Total organic carbon	A total organic carbon analyzer manufactured by the Laboratory Equipment Corporation (LECO) was used for the determinations of organic carbon. No attempt was made to correct results for errors due to CO_2 and CO_3.
8.	Filtered total carbon	The insoluble matter was separated from the solution by means of filtration. A sample of the solution was then analyzed with the "LECO" carbon analyzer. CO_2 was not removed prior to analysis.
9.	Total acids	A measured sample was put through a column containing Dowex D-50 ion exchange resin. This resin is the strong cation type which exchanges H+ ions for positively charged ions in the solution. The effluent from this column was then titrated with a standard solution of sodium hydroxide to the phenolphthalein end point.
10.	Ammonia nitrogen	The direct Nesslerization procedure as described in "Standard Methods for the Treatment of Water and Waste Water," 12th edition, was employed in this determination. The end results were obtained by a Hach DR Colorimeter, during the 1967-68 campaign. But during the 1968-69 campaign results were obtained by use of a Spectronic 20 (a Bausch & Lomb colorimeter-spectrometer) utilizing a standard calibration curve.
11.	Phosphate	Phosphates were determined, during the 1967-68 sugar year, by utilizing the stannous chloride reduction in an ammonium molybdate solution. Final results were obtained by the use of a Hach DR Colorimeter. A more complete description of this method may be found in the Hach DR Colorimeter manual for use with the Model 1104 Colorimeter. During the

TABLE 21. --(continued)

Analysis		Description
		1968-69 campaign ortho phosphate was determined by the method described in "Standard Methods for the Examination of Water and Waste Water," 12th edition, pp. 234-236.
12.	Alkalinity	A measured volume of sample was titrated against a standard acid or base solution to phenolphthalein end point.
13.	Solids	Solids analyses included total solids, total volatile solids, suspended solids, volatile suspended solids and settleable solids. Settleable solids were analyzed by means of an Imhoff cone; the other solids were analyzed by the procedure outlined in "Standard Methods for the Treatment of Water and Waste Water," 12th edition.
14.	Dissolved oxygen	Dissolved oxygen was analyzed according to the procedure described in "Standard Methods for the Treatment of Water and Waste Water," 12th edition; the azide modification of the Idometric method was used.
15.	$NO_3 + NO_2$-N	Analysis for NO_3 and NO_2 nitrogen were completed by adding Hach Nitraver + Nitriver powder pillows to samples and standard NO_3+NO_2 solutions. The final results were determined colorimetrically on a Spectronic 20, Bausch & Lomb Colorimeter.
16.	Organic acids	Organic acids were determined according to the procedure described in "Water and Waste Water Analysis Procedures," Volatile Acids section, p. 72. This manual was published August, 1967 by Hach Chemical Co. Final results were obtained colometrically utilizing a Spectronic 20 colorimeter and Standard Acetic Acid calibration curve.

TABLE 21.--(continued)

Analysis		Description
17.	Sulfates (SO_4)	Sulfate analyses were completed utilizing the gravimetric procedure described in "Standard Methods for the Examination of Water and Waste Water," 12th edition, pp. 287-290.
18.	Sulfites (SO_3)	Analyses for sulfite were completed utilizing the procedure described in "Standard Methods for the examination of Water and Waste Water," 12th edition, pp. 294-296.
19.	Sulfide	During the 1967-68 campaign sulfide analyses were completed by the method described in "Standard Methods for the Examination of Water and Waste Water," 12th edition, pp. 427 & 428. After the 1968-69 campaign sulfides analyses were completed utilizing a "La Motle-Pomeroy" Sulfide test kit.
20.	Coliforms	(APHA, Standard Methods, 12 ed., 1965) Appropriate aliquots of sample were placed in a Hydrosol filter funnel (Milipore) containing a 47mm type HA (pore size 0.45 u) white membrane filter (Milipore). In cases where the sample aliquot was less than 10 ml, there was a sterile buffered water carrier placed in the funnel to assure even distribution of the organisms on the surface of the membrane. Using a vacuum system, the sample aliquot was drawn through the membrane and the sides of the funnel were washed with 25-50 ml of buffered sterile water. The membrane was then placed in a petri dish (60 x 16 mm) containing an absorbent pad with 2.0 ml of m-Endo Broth MD (Difco) medium. The petri dish was placed in a moist chamber to prevent drying and incubated at 35°C for 18-24 hours at which time the plates were counted using a stereo disecting microscope with obique

TABLE 21.--(continued)

Analysis	Description
	lighting. Typical colonies were dark with a gold-green metallic sheen. (Difco Laboratories; Detroit, Michigan) (Millipore Corporation; Bedford Massachusetts)
21. Fecal streptococci	Aliquots of sample were filtered through a membrane filter as per coliform determination. Enrichment: (Rose and Litsky, 1965). In the lid of a petri plate with solidified m-Enterococcus Agar (Difco) in the bottom, an absorbent pad was placed with 2.0 ml of m-PYC (Difco) medium. The membrane was placed in a moist chamber and incubated at 35°C for 3-6 hours. Transfer and differential medium: (APHA, Standard Methods, 1965). At the end of the 3-6 hour enrichment, transfer the member to the surface of the m-Enterococcus Agar (Difco) in the bottom of the petri dish and continue incubating at 35oC for an additional 48 hours. All red and pink colonies were counted using a stereo dissecting microscope with oblique lighting.
22. Total aerobic count	(Millipore, 1969). Sample aliquots were filtered as per coliform test, but black membrane filters were used. The membranes were placed on an absorbent pad with 2.0 ml of m-Plate Count Broth (Difco) in a sterile petri plate and incubated in a moist chamber at 30°C for 48 hours. All colonies (0-300) were counted using a stereo dissecting microscope with oblique lighting. The black membrane eliminated the need for contrast staining to make all colonies easily distinguishable.

TABLE 21.--(continued)

	Analysis	Description
23.	Total anaerobic count	(Millipore, 1969) (Harris and Coleman, 1963). Sample aliquots were filtered through membranes as in the coliform determination; again the black membranes were used. The membrane was placed directly on the surface of solid Plate Count Broth (Difco) in a petri dish. This dish was placed in a dessicator jar which was evacuated and flushed with nitrogen three times. Finally with a slight vacuum remaining in the dessicator jar, it was sealed and incubated at 30°C for 48 hours. At this time, all colonies (0-300) were counted as in the total aerobic counting procedure. The solid medium eliminated the problem of drying which was encountered with a broth medium.

TABLE 22.--ANALYTICAL SCHEDULE; FPI, SPI, SPE FOR EACH WEEK OF CAMPAIGN; 1968-69.

Day	Tot sug	Tot CaO	Sol CaO	BOD	COD	Tot car	Tot acids	Alk	pH	Sol-ids	Org acids	D.O.
Mon				X	X	X		X	X	X	X	X
Tues	X	X	X		X	X	X	X	X	X	X	X
Wed	X	X	X	X	X	X	X	X	X	X	X	X
Thurs	X	X	X	X	X	X	X	X	X	X	X	X
Fri	X	X	X	X	X	X	X	X	X	X	X	X

Solids analysis included total solids, suspended solids, total dissolved solids and settleable solids.

Total carbon analysis was completed on daily samples until about the middle of campaign when a long period of inoperation of the carbon analyzer necessitated the compositing of daily samples into weekly samples for TOC.

Samples of FPI and SPE were taken by a mechanical sampler which drew sample at the rate of about 50 ml/minute on a cycle which was sampled from three to five minutes, every 20 minutes over a 24-hour period.

Samples of SPI were taken by a mechanical sampler which drew one sample per hour over a 24-hour period.

For control purposes hourly pH readings of the SPE were taken by the factory laboratory. Grab samples from FPI, SPI, SPE were analyzed for pH three times a day at eight hour intervals beginning each morning at 8:00 a.m.

TABLE 23.--ANALYTICAL SCHEDULE FOR EACH WEEK OF CAMPAIGN 1967-68.

Day	Tot sug	Tot Ca0	Sol Ca0	BOD	COD	pH	Tot C	Tot C filt	Odor and color	Tot acids	NH_3-N	P	Alk	Sol-ids
	FPI and SPE													
Mon*	X	X	X			X	X						X	
Tues**	X	X	X			X	X						X	
Wed***	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Thurs***	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fri***	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	APE****													
Mon		X				X	X	X			X	X		
Tues		X				X	X	X			X	X		
Wed				X	X	X	X		X		X	X		X
Thurs				X	X	X	X		X		X	X		X
Fri				X	X	X	X		X		X	X		X
	Condensed Water Effluent*****													
Mon														
Tues	X	X	X			X	X				X	X		
Wed	X	X	X	X	X	X	X				X	X		X
Thurs	X	X	X	X	X	X	X				X	X		X
Fri	X	X	X	X	X	X	X				X	X		X

*Solids analyses included total solids, suspended solids, total volatile and suspended volatile solids and settleable solids.

**A grab sample taken every 4 hours over a 16-hour period.

***A composite sample consisting of 8 individual samples taken at 1-hour intervals.

****A grab sample taken once a day.

*****A composite sample taken over a 24-hour period by a mechanical sampler taking 1 sample each hour. Analysis for dissolved oxygen was also completed on all 4 samples each week. (From Complementary Study.)

TABLE 24.--ANALYTICAL SCHEDULE FOR SAMPLES FOR BIOLOGICAL ANALYSIS; SPI, SPE, APDC FOR EACH WEEK OF CAMPAIGN 1968-69.

1.	pH	10.	PO_4, Total, Ortho
2.	Total Sugar	11.	$SO_4=$
3.	Organic Acids	12.	$SO_3=$
4.	Total Acids	13.	$S=$
5.	BOD_5	14.	Coliform
6.	COD	15.	Fecal Streptococci
7.	NO_3-N	16.	Total Aerobic Bacteria
8.	NO_2-N	17.	Total Anaerobic bacteria
9.	NH_3-N	18.	Solids (APDC)

Samples for biological analysis were taken twice per week and biological analysis was completed on both samples; chemical analysis was completed on a composite sample from both days.

SPI and SPE samples were grab samples, but the anaerobic pond sample was a depth composite.

The anaerobic pond depth composite was taken three days per week, and all three samples were analyzed for all measurements except nitrogen, sulfur and phosphorous containing compounds.

TABLE 25.--ANALYTICAL SCHEDULE, FIRST POND MUD SAMPLES, 1968-69.

1.	Total Solids	5.	Soluble CaO
2.	Suspended Solids	6.	Alkalinity
3.	Total Carbon	7.	pH
4.	Total CaO	8.	Specific gravity (wet)

The mud samples were weekly composites made from the mud which settled in an Imhoff cone from one liter of flume water. These were from the 24-hour composite of the first pond influent.

The flume water was decanted, and then the mud was washed into a collection jar with distilled water. All distilled water washings were saved. The mud sample and washings were transferred to a volumetric flask, heated slightly, cooled and made to volume after specific gravity analysis was completed on a water decanted sample.

TABLE 26.--PHYSICAL DATA SCHEDULE; 1968-69 CAMPAIGN

Temperature

1. First Pond Influent - Twice daily
2. Second Pond Effluent - Twice daily
3. Anaerobic Pond Depth - Once daily
4. Anaerobic Pond Effluent - Once daily
5. Condenser H_2O - Once daily at river.

Charts*

1. First Pond Influent - Weekly flow chart
2. Second Pond Effluent - Daily pH chart
3. East Holding Pond Influent - Weekly flow chart
4. Flume System Overflow, factory - Daily flow chart
5. Condenser water, effluent - Weekly flow chart

Gauge and Meter Readings

1. Recirculation flow - Twice daily
2. Anaerobic Effluent** - Once daily
3. Anaerobic make up - Once daily
4. Anaerobic Pond Depth*** - Once daily

*Maintenance and calibrations were performed on a periodic schedule.
**Anaerobic pond effluent flow was calculated from gauge readings of a Parshall flume.
***Anaerobic pond depths were taken from a standing gauge.

TABLE 27.--ANALYTICAL SCHEDULE, CONDENSER WATER AND MISCELLANEOUS FACTORY EFFLUENTS IMPOUNDED FOR EACH WEEK OF CAMPAIGN 1968-69.

Day	pH	Tot C	BOD	COD	Tot CaO	Sol CaO	Tot Sug	Sol-ids	Tot acids	Org acids	D.O.	NH_3 N	NO_3 N	NO_2 N	PO_4
Condenser Water															
Mon	X	X	X	X				X			X				
Tues	X	X		X	X	X	X	X	X		X	(	Weekly		)
Wed	X	X	X	X	X	X	X	X	X		X	(	Composite		)
Thurs	X	X	X	X	X	X	X	X	X		X	(			)
Fri	X	X	X	X	X	X	X	X	X		X				
Miscellaneous Factory Effluents, Discharged to Holding Pond															
Mon	X	X	X	X				X		X	X				
Tues	X	X		X	X	X	X	X	X	X	X	(	Weekly		)
Wed	X	X	X	X	X	X	X	X	X	X	X	(	Composite		)
Thurs	X	X	X	X	X	X	X	X	X	X	X	(			)
Fri	X	X	X	X	X	X	X	X	X	X	X				

Solids analysis included total, suspended, dissolved and settleable solids.

Total carbon analysis was completed on daily samples until about the middle of campaign after which the samples were weekly composites.

Nitrogen and phosphorus analysis were completed on weekly composite samples.

East holding pond samples were daily grab samples until about the middle of campaign, after which these samples were taken by a mechanical sampler which took one sample every hour over a 24-hour period.

Condenser samples were taken by a mechanical sampler which took one sample every hour, over a 24-hour period, until about the middle of campaign after which they were daily grab samples.

TABLE 28.--ANALYTICAL SCHEDULE; ANAEROBIC POND SAMPLES; 1967-68 POST CAMPAIGN; FEBRUARY 3 TO MARCH 28, 1968; THREE SAMPLES PER WEEK.

1.	BOD
2.	COD
3.	D.O.
4.	Temperature
5.	pH

TABLE 29.--ANALYTICAL SCHEDULE (TWICE WEEKLY); ANAEROBIC POND; 1968-69 POST CAMPAIGN; FEBRUARY 3 TO MARCH 28, 1969.

1.	pH
2.	BOD_5
3.	COD
4.	D.O.
5.	Solids*
6.	Organic Acids
7.	Total Acids
8.	Ammonia Nitrogen**
9.	Nitrate Nitrogen**
10.	Nitrite Nitrogen**
11.	Sulfate
12.	Sulfide
13.	Phosphate, Soluble, Ortho**
14.	Total CaO
15.	Soluble CaO**
16.	Pond Temperature
17.	Pond Depth
18.	Coliform***
19.	Fecal Streptococci***
20.	Total Anaerobic Bacteria***
21.	Total Aerobic Bacteria***

*Solids analysis included only non-volatile suspended and dissolved solids.

**Analysis completed once per week on a composite sample made from all separate samples taken during the week.

***Analysis completed on two samples per week.

TABLE 30.--ANALYTICAL SCHEDULE, ANAEROBIC POND SAMPLES; 1968-69 POST CAMPAIGN; APRIL 2 TO JULY 9, 1969; ONE SAMPLE PER WEEK.

1. pH
2. BOD_5
3. COD
4. Solids*
5. Organic Acids
6. Total Acids
7. Ammonia Nitrogen
8. Nitrate plus Nitrite Nitrogen
9. Sulfate
10. Sulfide
11. Phosphate, Soluble, Ortho
12. Total CaO
13. Soluble CaO
14. Pond Temperature
15. Pond Depth
16. Coliform
17. Fecal Streptococci
18. Total Anaerobic Bacteria
19. Total Aerobic Bacteria

*Solids analysis included volatile and non-volatile, dissolved and suspended solids.

TABLE 31.--ANALYTICAL SCHEDULE (WEEKLY); ANAEROBIC POND SAMPLES; 1968-69 POST CAMPAIGN; JULY 17 TO SEPTEMBER 3, 1969.

1. pH
2. BOD_5
3. COD
4. Ammonia Nitrogen
5. Phosphate, Soluble, Ortho
6. Pond Temperature
7. Pond Depth
8. Solids*&**
9. Organic Acids**
10. Nitrate plus Nitrite Nitrogen**
11. Sulfide**
12. Total CaO**
13. Soluble CaO**
14. Coliform**
15. Fecal Streptococci**
16. Total Anaerobic Bacteria**
17. Total Aerobic Bacteria
18. Algae**

*Solids analysis included volatile and non-volatile, suspended and dissolved solids.
**Completed on an occasional basis.

TABLE 32.--ANALYZED SUBSTANCES* ENTERING AND LEAVING THE FIRST AND SECOND PONDS IN SERIES, SHOWING PERCENTAGE REMOVED BY THE PONDS PER TON OF BEETS SLICED; 1968-69 CAMPAIGN AVERAGE.

Analyses	Pounds, per ton of beets, entering first pond	Reduction (or increase) across both ponds	Pounds, per ton of beets, residual in pounds	% reduction
BOD_5	2.76	-2.08**	0.68	75
COD	2.77	-1.74	1.03	63
Soluble CaO	0.61	-0.34	0.27	56
Total CaO	1.40	-1.12	0.28	80
Dissolved Solids	3.13	-1.68	1.45	54
Total Carbon	2.03	-1.53	0.50	75
Total Sugar***	2.24	-1.93	0.31	86
Total Acids****(as CaO)	-	+0.31	0.42	-
Organic Acids****(as CaO)	-	+0.59	0.52	-

*Calculated on static pond volume basis and as if no physical loss and subsequent dilution occurred.

**Minus sign designates reduction, plus sign designates increase.

***Calculated ssing periods characterized by high pond pH, where sugar concentration showed a tendency to increase.

****Increase across ponds approximately equal to residual in ponds, so no reduction occurred.

TABLE 33.--PRIMARY POND INFLUENT, 1967-68 CAMPAIGN, COMPOSITE SAMPLE ANALYSIS FOR BOD, COD, TOC, FILTERED TOC, ORGANIC ACIDS, TOTAL CaO, SOLUBLE CaO, ALKALINITY, pH.

Date	BOD_5*	COD*	TC	Filt TC*	Org Acids	Tot CaO**	Sol CaO**	Alk**	pH
10-18	240	625	210	170		440	270		8.0
10-19		350	290	220		400	320		7.2
10-[illegible]4	220		210	220		610	440		12.2
10-[illegible]	260		320	230		420	450		12.2
10-26	510	900	320	260		770	460		12.4
10-31	770	1,350	640	500		460	320		9.4
11-1	450	1,090	420	290		610	320		7.4
11-2	430	850	420	270		560	370		12.4
11-7	610	880	340	290		510	380		6.9
11-8	660	900	370	270		570	380		7.1
11-9	480	480	550	300		550	371		7.4
11-14	330	840	250	280	370	410	370	0	7.2
11-15	340	1,360	240	230	240	430	350	0	8.6
11-16		1,200	390	310	140	570	170	25	10.8
11-21		1,252	510	360	330	330	340	10	9.6
11-22	930	1,252	550	460	280	390	280	0	10.5
11-28		1,560	770	530	360	760	370	8	10.9
11-29		1,372	640	500	390	790	440	54	11.9
11-30		1,280	640	570	430	630	500	16	11.7
12-5	1,250	2,344	1,050	780	290	580	310	22	11.6
12-6	1,200	1,880	990	720	280	560	320	42	11.4
12-7	1,340	2,304	1,020	880	280	590	340	60	11.8
12-12	2,060	5,400	1,270	850	520	530	520	0	9.0
12-13	1,510	2,740	990	760	520	810	520	0	10.3
12-14	1,430	1,920	780	670	520	610	520	0	8.5
12-19	1,250	1,920	850	670	600	680	600	0	8.4
12-20	1,240	1,960	770	630	520	630	520	0	8.0
12-21	1,280	2,240	750	620	530	700	530	0	8.0
12-26		2,220	780	530	470	630	470	0	6.6
12-27		1,900	690	500	480	730	480	0	6.8
12-28		1,340	670	550	470	490	470	0	6.5
1-2	930	1,160	240	180	310	480	310	0	9.0
1-3	530	660	340	310	310	350	310	0	7.0

*Parts per million
**Parts per million as CaO

TABLE 33. --(continued)

Date	BOD_5*	COD*	TC	Filt TC*	Org Acids	Tot CaO**	Sol CaO**	Alk**	pH
1-4	560	500	300	270	300	410	300	0	7.8
1-9	1,470	1,660	690	650	340	340	340	0	6.3
1-10	790	1,260	450	350	350	450	330	0	7.0
1-11	760	2,000	390	380	330	350	340	0	6.5

*Parts per million
**Parts per million as CaO

TABLE 34. --DILUTION EFFECT ON pH IN PRIMARY POND OF FRESH MAKE-UP WATER ADDED TO SYSTEM; 1967-68 CAMPAIGN.

Date	Hours of dilution	Million gallons added	Lbs. lime added/hr.	Begin pH	End pH
10-19	8.0	1.18	275	10.5	9.5
10-23	8.0	0.36	600	9.9	8.5
11-2	8.0	0.52	600	10.3	9.7
11-6	4.0	0.42	150	10.5	9.2
11-7	7.0	1.10	150	9.5	8.6
11-7	6.0	0.41	150	9.1	8.0
11-8	1.5	0.23	150	9.2	8.4
11-10	4.0	0.02	300	10.2	9.8
11-14	7.0	1.03	300	10.8	9.1
11-16	16.0	1.78	425	11.2	9.4
11-27	7.0	0.34	515	10.2	9.6
12-2	10.0	0.05	150	9.9	9.8
12-8	3.0	0.18	100	11.5	9.3
12-13	4.5	0.09	400	11.2	9.0
12-27	7.0	0.34	200	9.8	9.0
12-28	16.0	0.44	200	10.5	9.0
12-30	14.5	1.48	200	11.0	9.0

APPENDIX III

TABLES

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COMPLEMENTARY STUDY I

Effect of Polymer Flocculents on Fluming System

During the last month of the 1968-69 campaign the decision was reached to test the affects of a polymer flocculent on the recirculated flume water system. The objective of this study was to determine the affects of the flocculent on pH control, settling efficiency, and bacteriological activity.

Theoretically, the flocculents should increase settling efficiency by removing a greater percentage of the smaller, collodial-like suspended solids. If these solids were organic in nature, their removal would reduce the substrate for the bacteria to thrive on, therefore, less bacteria and less organic acid production should result. It has been reported (36) that certain bacteria types can be removed by utilizing settling aids.

Prior to this study bench scale tests were completed using Nalco Chemical Company products to determine which flocculent would achieve the best results in this system. The bench study indicated that of the products tested, both Nalcolyte 670 and Nalcolyte 674 would achieve the best results; both products would achieve comparable results at equivalent concentrations. Nalcolyte 670 was chosen as the flocculent to be added to the flume water system because this flocculent can be made up in a more concentrated stock solution than the Nalcolyte 674. Several Calgon products were also tested on the bench and the results indicated that Calgon 226 and Calgon 235 would work as well as the Nalco products at comparable concentrations. Each of the flocculents used had been cleared by the Food and Drug Administration for use in sugar refining processes.

Three stainless steel tanks with about 175 gallon capacities and equipped with propeller type mixers were utilized for mixing and aging the flocculent stock solution. The stock solution was prepared by using a special dispersion funnel. The concentration of this solution was 0.5 percent by weight. The stock solution was pumped to a "header" which dispersed the flocculent into the first pond influent just ahead of the mixing box. Dilution water was added to the flocculent stream to achieve more dispersion of the flocculent before its entry into the fluming waters. The ratio of dilution water to flocculent stock solution was greater than 1.2 to 1 during the period in which 1 ppm flocculent was added and greater than 2.4 to 1 when 0.5 ppm was being added. For the first two days of this study .77 and .80 ppm flocculent were added to the flume water and for

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the last 2 days 0.39 and 0.47 ppm.

Samples were taken at the first pond influent, second pond influent, and second pond effluent by mechanical samplers operating over a 24-hour period. These samples were analyzed for the following:

1. Clarity (Read as percent transmission on a Bausch and Lomb "Spectronic 20" colorimeter. Sample was diluted 1:4 before analysis.)

2. Control pH (pH taken from SPE by factory laboratory every hour over a 24-hour period.)

3. Suspended solids (Analyzed by filtering sample through a tared Gooch crucible with asbestos mat, drying and reweighing.)

4. Bacteria population (A once per day grab sample analyzed by Department of Microbiology at Colorado State University at Fort Collins, Colorado.)

Clarity

Previous to the flocculent addition the clarity at the SPI was 6.3 percent transmission and 3.5 percent at the SPE (Table 35). Upon the addition of 0.77 ppm flocculent, the clarity at the SPI increased to 24.2 percent; but the clarity at the SPE remained low. It is thought that one day was necessary to effectively treat all the system waters, as on the second day of flocculent addition the clarity at both points was at about the 27-28 percent level. Flocculent was added at a 0.80 ppm concentration the second day.

Cutting the addition of flocculent added to the system in half had the effect of lowering the clarity somewhat at both points. The improvement in clarity upon the addition of flocculent indicated that the product increased the settling efficiency of the system and removed a percentage of the fine, collodial like suspended solids.

Suspended Solids

At the time this study was undertaken, both primary ponds were almost full, and a larger than usual amount of suspended solids was being carried over into the second pond. This time period was also characterized by the formation of an unusually large amount of suspended solids in the second pond by the formation of biological sludge, chemical precipitants, etc.

TABLE 35.--NALCOLYTE 670 ADDITION TO LONGMONT FLUME WATER SYSTEM

Day Number	1			2		
Day ending date	1-21-69			1-22-69		
Flocculent addition ppm on flow	0.00			0.77		
	FPI*	SPI*	SPE*	FPI	SPI	SPE
Suspended solids ppm	6,300	2,400	2,730	4,000	680	1,900
Percent transmission 1+3 solution		6.3	3.5		24.2	6.2
Settling efficiency % difference susp sol**		62.0	56.7		83.3	53.4
Pounds susp solids settled, first pond		145,700			156,800	
Pounds increase secondary pond		14,300			56,200	
Pounds lime added		7,200			9,600	
Control pH (SPE)		7.0			7.5	
Bacterial numbers (average in system)						
1. Coliform mpn/100ml		6,800			11,800	
2. Fecal strep 10^6mpn/100ml		1.9			3.1	
3. Aerobic 10^6mpn/100ml		208			120	
4. Anaerobic 10^6mpn/100 ml		280			380	

*FPI - First Pond Influent; SPI - Second Pond Influent; SPE - Second Pond Effluent

**Calculated from FPI suspended solids less SPE suspended solids

TABLE 35.--(continued)

Day number	3			4			5		
Day ending date	1-23-69			1-24-69			1-25-69		
Flocculent addition ppm on flow	0.80			0.47			0.39		
	FPI	SPI	SPE	FPI	SPI	SPE	FPI	SPI	SPE
Suspended solids ppm	2,300	670	670	1,600	680	860	1,800	1,300	
Percent transmission 1+3 solution		27.0	28.0		26.8	26.3		24.0	26.0
Settling efficiency % difference susp.sol.**		71.2	70.9		56.0	45.0		27.7	
Pounds susp solids settled, first pond	72,200			37,820			19,800		
Pounds increase secondary pond	350			7,600					
Pounds lime added	7,200			7,200			7,200		
Control pH SPE	6.8			6.8			6.8		
Bacterial numbers (average in system)									
1. Coliform mpn/100 ml	9,600			73,300					
2. Fecal strep 10^6mpn/100 ml	3.8			2.9					
3. Aerobic 10^6mpn/100 ml	420			52.5					
4. Anaerobic 10^6mpn/100 ml	420			190					

The addition of approximately .80 ppm flocculent increased the removal of suspended solids from 62 percent to approximately 70-80 percent and effectively settled the equivalent of all suspended solids formed in the second pond before discharge from the second pond, as suspended solids concentration at the SPI and SPE were approximately equal on the second day of 1 ppm addition. Cutting the flocculent addition in half lowered the settling efficiency and raised the amount of solids being carried across the second pond.

pH

The addition of flocculent in the specified concentrations did not affect a significant rise in control pH at a fairly consistent level of lime addition.

Biological Propagation

The flocculent addition did not seriously hamper bacteriological propagation in the fluming waters.

Foam

The use of heated flume water and flocculent apparently produced a large amount of foam which hampered fluming operations.

Conclusions

At a concentration of about .80 ppm of Nalcolyte 670 polymer flocculent the settling efficiency and clarity of the flume water system were improved significantly. However, when the addition was lowered to 0.5 ppm the system efficiency and clarity decreased.

The addition of flocculent at the aforementioned concentration levels did not effect a rise in control pH, at a lime addition rate of 300 to 400 pounds/hour, or seriously inhibit bacterial propagation and activity.

The combination of heated flume water and flocculent apparently produced unusually large amount of foam which hampered plant operation.

COMPLEMENTARY STUDY II

Goodland Spray Cooled Condenser Water System

In the interest of total water pollution control, several miscellaneous factory systems were sampled and analyzed. One of the systems studied was the spray cooled recirculated condenser water system at the Great Western sugar factory in Goodland, Kansas.

The hot condenser water from the factory flows into a receiving pond after passing through typical spray heads used for evaporative cooling. Grab samples were taken from the influent and effluent streams of this pond twice during the 1968-69 sugar campaign.

Prior to the analysis of the Goodland spray pond samples, it was thought that the solids and BOD_5 in this type system might increase as campaign progressed. However, the results of the analysis of the two sets of grab samples, taken 22 days apart, do not show a build-up tendency when the system was operating normally. Instead these samples show decreasing concentrations with respect to time (Table 36).

Phosphate was absent at both sampling periods and total inorganic nitrogen measured was 14.2 ppm into and 13.1 out of the spray pond, the major constituent being ammonia nitrogen. No major increases were noted during the 22 day sampling interval in either contaminants or nutrients.

TABLE 36.--GOODLAND SPRAY-COOLED CONDENSER WATER.

Sample Station	Spray pond influent	Spray pond effluent	Spray pond influent	Spray pond effluent
Temperature C°	50	28	52	31
pH	8.9	8.7	8.2	8.7
BOD_5 ppm	71	52	12	15
COD ppm	115	77	62	39
Total sugar ppm sucrose	61	41	0	0
Nitrate nitrogen ppm	1.1	0.9	0.7	0.9
Nitrite nitrogen ppm	0.1	0.2	0.3	0.3
Ammonia nitrogen ppm	13	12	13	15
Phosphate, soluble, ortho, ppm	0	0	0	0
Suspended solids ppm	65	16	0	0
Dissolved solids ppm	335	312	178	202

COMPLEMENTARY STUDY III

Gas Washer and Flash Cooler Water

Grab samples were taken from the gas washer and flash cooler effluents at the Longmont factory and analyzed to determine the qualitative nature of these waste streams. Positive conclusions cannot be drawn from one sampling session, however, several results of this study should be noted.

The main contaminant from the flash cooler appears to be ammonia nitrogen, as BOD and COD levels were fairly low and phosphate was absent (Table 37). The gas washer water appears to be low in nutrient concentration.

The large differential between COD and BOD concentrations in the gas washer water would indicate that a large percentage of the carbonaceous compounds were difficult to degrade biologically. The gas washer water contained a large amount of carbon dioxide which probably formed insoluble carbonates in a limed environment.

TABLE 37.--FLASH COOLER AND GAS WASHER ANALYSIS, 1968-69 CAMPAIGN, LONGMONT FACTORY.

Sample station	12-26-68 Flash cooler	11-19-68 Gas washer
pH	9.0	6.0
BOD_5 ppm	47	11
COD ppm	54	65
Dissolved oxygen ppm		6.2
Ammonia nitrogen ppm	48	5
Nitrate nitrogen ppm	2.7	1.5
Nitrite nitrogen ppm	0.1	0.1
Phosphate, soluble, ortho, ppm	0	0
Carbon dioxide ppm		551
Suspended solids ppm	85	89
Dissolved solids ppm	849	720

COMPLEMENTARY STUDY IV

Foam Control

The recirculated flume water system produced large amounts of foam when control pH was high (10.0-12.0) and lesser amounts when control pH was low (<10.0). The foam presented a problem in the flumes and in the beet laboratory tare house.

The foam was controlled in the tare house by injecting Exfoam 440, a product of the Dearborn Chemical Division of W. R. Grace and Company. into the tare house influent flow with a positive pressure pump. Approximately 3 gallons per day of this product was used for foam control.

Several other defoaming agents were used successfully for foam control in the overall flume water system. These products were:

	Name	Manufacturer	Amount gallons/day
1.	Hodag PX 88	Hodag Chemical Co.	25
2.	Mazu 103	Mazer Chemical Co.	25

COMPLEMENTARY STUDY V

Condenser Water and Miscellaneous Factory Effluents

During the 1967-68 campaign the condenser water and miscellaneous factory effluents were discharged as one stream, but during the 1968-69 campaign the condenser water was separated from the other wastes and discharged as a separate stream. Therefore, an additional sampling station was added during 1968-69 and was designated "East Holding Pond Influent" (EHPI). The EHPI contained the following flows:

1. Spillage from flume system
2. Acid and caustic boil outs
3. Floor drains
4. Steffens wash out

During the 1967-68 campaign this total discharge (Condenser and Miscellaneous) was sampled by a "Serco" automatic sampler which took one sample each hour over a 24-hour period. The 24 samples were combined by equal parts by volume into a daily composite sample. (Table 25 shows analytical schedule.) The flow rate of this discharge was measured by a Parshall flume which was equipped with a level recorder.

During the 1968-69 campaign the condenser water flow was measured with an overflow wier which was equipped with a stilling chamber and level recorder. This flow was sampled once each hour on a 24-hour basis by a mechanical sampler for the first half of the campaign; it was sampled on a one grab per day basis for the last half of the campaign.

The EHPI flow was measured by a Parshall flume, stilling well and level recorder for the 1968-69 campaign. It was sampled on a one grab per day basis for the first half of campaign. During the second half of campaign it was sampled by means of an automatic sampler each hour on a 24-hour schedule.

It is interesting to note that for 1967-68 the total factory discharge (condenser water and miscellaneous wastes) had an average dissolved oxygen (D.O.) content of 2.8 ppm, (Table 38) but during the 1968-69 campaign the condenser water had an average D.O. content of 4.6 ppm and a range of 3.0 to 6.5 ppm, while the EPHI had an average D.O. content of 0.6 ppm

and a range of from 0.5 to 5.1 ppm (Table 39).

The primary objectionable qualities of pure condenser water appeared to be the total nitrogen content and high temperature. At this particular location on the receiving stream (State of Colorado Agricultural Use classification), pure condenser water was in compliance with discharge standards.

The miscellaneous factory effluents, on the other hand, showed a high degree of variability in contaminants. Although the flow is quite low, it is evident that combined miscellaneous wastes do need treatment before discharge to a receiving water body. Such treatment would include settling facilities for removal of suspended solids and facilities for bi-degradation of dissolved solids.

TABLE 38.--CONDENSER WATER, 1967-68 CAMPAIGN, AND MISCELLANEOUS FACTORY DISCHARGES

	Range		
	High	Low	Mean
pH	11.7	6.1	8.7
BOD_5 ppm	799	47	344
Total organic carbon ppm	692	92	242
COD ppm	1,440	48	464
Total sugars ppm, sucrose	711	20	75
Dissolved oxygen ppm	5.2	0.2	2.8
Total CaO ppm	1,061	251	423
Soluble CaO ppm	564	180	261
Ammonia nitrogen ppm	46	8	21
Phosphate ppm	1.9	0.1	0.5
Suspended solids ppm	2,850	124	841
Volatile suspended solids ppm	320	8	123
Dissolved solids ppm	2,380	636	1,105
Volatile dissolved solids ppm	1,054	118	462
Temperature C°	53	36	43

TABLE 39.--CONDENSER WATER AND EAST HOLDING POND INFLUENT, AVERAGE RESULTS, 1968-69.

	Condenser Water			East holding pond influent		
	High	Low	Average	High	Low	Average
pH	8.9	7.9	8.6	12.8	6.4	12.0
BOD_5 ppm	72	3	21	14,968	170	2,959
COD ppm	206	3	44	164,409	353	4,715
Dissolved oxygen ppm	6.5	3.0	4.6	5.1	0.0	0.6
Soluble CaO ppm	547	203	315	3,503	179	1,061
Total CaO ppm	1,349	217	346	6,055	394	2,027
Total sugar ppm sucrose	35	--	5.5	32,740	0.0	3,671
Settleable solids ml/L	0.4	--	.02	50.0	0.8	21.5
Dissolved solids ppm	1,128	550	836	61,178	1,056	1,866
Suspended solids ppm	368	--	36	11,813	88	6,664
Total acids ppm CaO	546	217	296	2,729	156	590
Organic acids ppm acetic	--	--	--	2,338	0.0	446
NH_3-N ppm	18	--	9	82	0.0	22
NO_3-N ppm	1.4	0.9	1.0	50.1	0.50	14.8
NO_2-N ppm	0.7	0.1	0.4	2.9	0.12	1.0
Phosphate ppm ortho	0.5	--	.05	19.8	2.0	8.3
Temperature °C	49	21	38	57	15	30
Flow gpm	7,732	5,398	6,569	281	133	190
Total carbon ppm	160	--	60	29,100	240	1,641